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ROAD CONSTRUCTION AND MAINTENANCE

PRIZE ESSAYS

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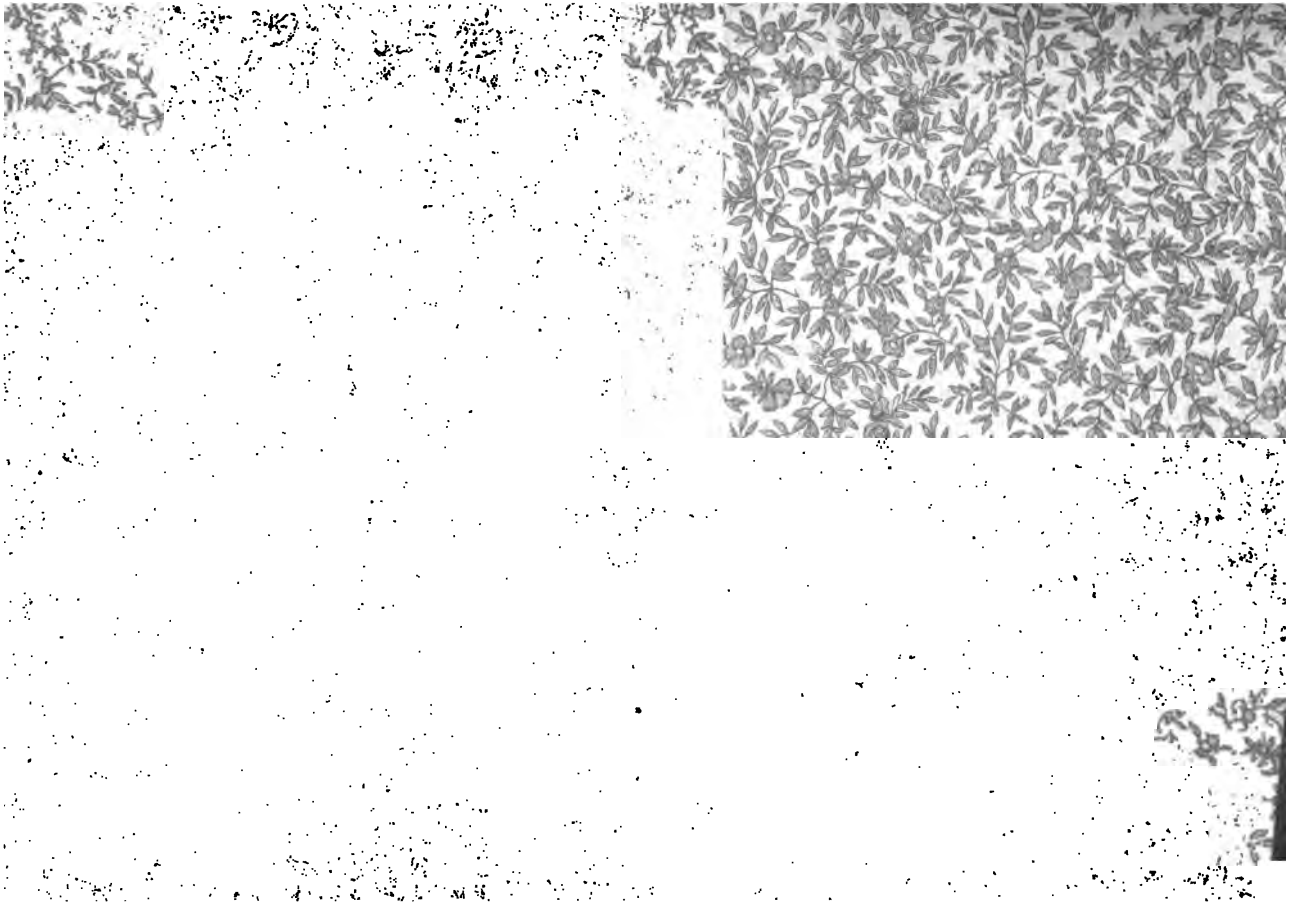

Dr. John S. Billings,
U. S. Army.

ROAD CONSTRUCTION

AND

MAINTENANCE.

PRIZE ESSAYS

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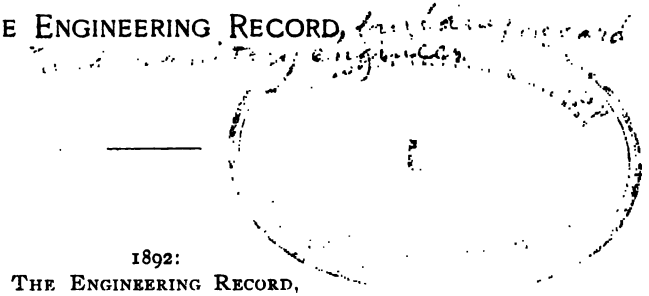

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INTRODUCTION.

THE widespread and constantly growing interest in the construction of better roads has resulted in a demand for a condensed hand-book on road building and maintenance. Recognizing this demand, THE ENGINEERING RECORD, in 1890, instituted a Prize Competition for Essays on this subject. Three judges, of wide experience in the construction and maintenance of highways, read these Essays, and their criticisms, with the Prize Essays, appear in the following pages, which give timely information of practical value.

The following from *The Engineering Record*, of March 29, 1890, refers to the matter found on the following pages:

The Competition for Essays on Road Making and Maintenance, instituted by *The Engineering Record* has, like the Competition for Water Tower and Pumping Station Designs, proved very successful. The Competition closed March 1, and the 21 essays received have in the intervening time received the careful consideration of the Committee of Award.

At a time when there is such a general awakening to the importance of having good roads, this valuable contribution to the literature of the subject is most opportune. In addition to the Prize Essays, we are happy to announce a discussion of certain features in the several essays by the Committee of Award, which, in view of the experience of these gentlemen, will add materially to the practical results of this competition. The following is the report of the Committee:

To the Editor of THE ENGINEERING RECORD:

The Committee invited by you to award prizes amounting to $150 for Essays on Road Construction and Maintenance have examined the 21 papers submitted to them, and make the award as follows:

"CESA." *First Prize*, $75.

S. C. THOMPSON, 832 East One Hundred and Sixty-first Street, New York City.

"BONA VIA, BONUM OPUS." *Second Prize*, $50.

I. F. POPE, 905 Brazos Street, Austin, Tex.

"A SIMPLE SCRATCH." *Third Prize*, $25.

JOHN P. PRITCHARD, Quincy, Mass.

Also as worthy of Honorable Mention, abstracts of each to be published, we would name the following:

"GRANITE STATE."

PROF. JOHN V. HAZEN, Chandler Scientific School, Hanover, N. H.

"PALISADES."

SAMUEL L. COOPER, Engineer Finance Department, City of New York.

"ROY."

FRANK B. SANBORN, Brookline, Mass.

"ZAMORA."

A. T. BYRNE, Civil and Mining Engineer, 361 Fulton Street, Brooklyn, N. Y.

As a brief declaration of principles, "TO THE POINT," A. L. PHILLIPS, Pencoyd, Pa., is also worthy of publication.

The result of this competition is a matter for congratulation, and the essays are, as a whole, a contribution to the literature on this important subject both valuable and practical. We do not wish, however, to be understood as indorsing every proposition made in any one of the papers.

At a future time we will submit a brief criticism that we think should go on record with the essays herewith recommended for publication.

F. COLLINGWOOD,
EDWARD P. NORTH,
JAMES OWEN.

COMMENTS BY THE COMMITTEE OF AWARD.

The following comments are made by the Committee of Award, upon various propositions made in the several essays:

Tractions.—Refinements as to traction are of little practical value. In every case it is desirable to fix upon a maximum grade. This being done, no exceptions should be allowed other than for very short distances. Authorities differ as to the power of horses, and as to the traction resistance of various road surfaces.

Alterations in Grade.—It will not do to say that these must not be allowed. The "lay of the land" and other circumstances will often compel their adoption; the only alternatives often being either a great increase in expense, or great detriment to adjacent property.

The "Angle of Repose of Vehicles."—Much stress has been laid on the requirement that descending grades shall not exceed this. We believe the refinement an impossible one. What will be true for one vehicle with a certain width of tire, size of wheels and axles, state of lubrication and amount of load carried will be different for another vehicle, varying essentially in these particulars.

Again, what will be true for a given vehicle with the road dry and in perfect condition, may not be true when wet, frosty, etc.

These latter variations will be less the harder and more perfect the road surface.

Width of Road-Bed.—We think the width of road metal or other covering should not be less than 16 feet, except where all traffic is very slow, where 12 feet may answer. This is a matter for the judgment of the engineer.

Cost of Handling Earth.—No fixed rules can be given as to this, as it depends so largely upon location, cost and kind of labor and teams, and thorough management. The remarks on the cost of handling earth, it should be remembered, are based on wages paid "before the war," when 75 cents a day was nearer an average than one dollar. It is a matter of regret that in this connection no mention was made of the cost of scrapper work, and that no essayist described the working of a "road machine," an extremely valuable implement in forming and maintaining earth roads.

Weight of Roller.—It is obvious that no road roller can be made heavy enough to give the same pressure per inch as the heaviest loaded wheel, but we think the use of a 10 to 15 ton roller advisable where it can be had.

Binding Material.—The question of the amount of binding to be used is largely dependent on the amount of rolling done, and the subsequent care of the roads. It is admitted that a considerable saving can be made by using more binding and less rolling, and where money must be made to go as far as possible this expedient is justifiable.

We think, however, it cannot be questioned that heavy rolling with a moderate amount of binding, preferably screenings, gives a more durable and cleaner surface under heavy traffic.

Thickness of Pavement.—This is to be decided by a due consideration of all the circumstances in each particular case, and should be left to the judgment of the engineer. It is rarely the case that every part even of the same road needs the same treatment. Retentiveness of the soil, gradients, thoroughness of drainage possible, climate, character and extent of traffic, and amount of money available, all have to be considered, and we deem it unwise to try to lay down hard-and-fast rules on this all-important matter.

Asphaltic Pavements.—The remarks of "Cesa" on asphalt pavements are unfortunate, as there is an entire lack of distinction between the various kinds of pavements going under this name; and the essayist, by implication, condemns pavements that are satisfactory, on purely theoretical grounds.

There is one direct error in statement, also, by this writer, that attention should be called to. He states that in England roads are under national supervision. The English highways are under supervision that varies in extent from the bounds of a single parish to that of a county, and while the great mass of American roads are bad enough, it is thought that no roads have been anywhere built that were better than those built by the New York Central Park Engineers, in and about the Park, and we doubt if any European country can show better surfaced country roads than many in New Jersey, Massachusetts and Connecticut.

Berms and Ditches.—The arrangement of berms and ditches in the second prize essay is questionable, except on sandy soils.

Foundation of Telford Roads.—As there seems to be some discrepancy of statement in the several papers as to

the foundation blocks in Telford pavement, we desire to state that in no case must such stone lie on the flat or broad side of the stone. The broadest edge should be down, the stone set lengthwise across the street, breaking joints in the several rows. The stones in any one row should be approximately of the same thickness. Very thick stones are bad for durability. Every needless refinement in road-making costs money, and while engineers should exact close attention to details upon which durability depends, it is not wise to expend the minute care upon them that might be bestowed upon a city street.

Repairs.—Where money is scarce, repairs may be made more cheaply and so as to answer a good purpose by the use of road metal, with enough clay or loam with it to make it compact quickly. One of the greatest enemies of Macadam roads is the wind, and to prevent the effects of winds the rolling and repairing of the surface as soon as is practicable in the spring, is one of the effective means.

Water, sand, clay, or loam should be promptly used if a road begins to break up in the spring winds.

In making repairs, we doubt whether it is advisable (in the case of trap Macadam at least) to break up the surface with spikes or with picks, where water for softening the road is available.

The circumstances under which it is advisable to use material from ditches, a practice usually condemned, are not fully brought out. Washed coarse sand and gravel from side ditches may make a valuable addition to the road-bed, but the mud and fine sand washed from this will not add to the wear of the road-bed.

Stone Breakers.—Where suitable stone is available for road-making, a town owning a stone-breaker is more apt to have a sufficiency of road metal than where a vote has to be passed for the expenditure of a definite sum of money at intermittent times; but if the demagogue could be eliminated from the town meeting, it would sometimes be the case that the broken stone could be purchased more cheaply from a large establishment making the breaking of stone a business.

County and Assistant Engineers.—We consider the remarks on this subject in the second prize essay ill-advised. The qnestion of time has less to do with the capabilities of a man for such work than natural ability and habits of reasoning observation.

No engineer should be required to waste his employer's time by walking five miles. The better arrangement is to furnish at all times such horses and conveyance as may be required.

F. COLLINGWOOD.
EDWARD P. NORTH.
JAMES OWEN.

ROAD

CONSTRUCTION AND MAINTENANCE

BY S. C. THOMPSON ("CESA"), NEW YORK.

In writing upon this subject, it is the intention of the author to treat the different matters under consideration so as to present the method of doing the work, and the reasons for it, in a manner to be easily grasped by the popular mind, rather than to collate and arrange information for the professional reader.

Commencing with Road Construction, it can be divided into—first, locating, or laying the road; second, making the road-bed, which includes all earthwork, drainage, and everything necessary to get the foundation in proper shape; and third, surfacing, or making the top of the road.

Location.—First, let us see what are the elements which affect the location of a road, and upon what is the location of a road dependent.

The problem in its simplest form is, of course, given two or more points to be connected by a roadway, without any limitations whatever; but the usual considerations which

determine where a road shall be built are often varied and troublesome.

Elements that Determine Location.—Taking them in the order in which they are likely to occur, we have, first, the amount of money that can be expended, and as a necessary part of this, and largely determined by it, second, the allowable grades, and maximum curves permissible.

Select Best Possible Route.—When it has been determined to connect two places with a road, the best possible route over which to build the road should be determined, and then the construction should conform, as nearly as the contingent circumstances will permit, to the location laid down.

Make the line as nearly straight as practicable, and when changes of line occur connect them by regular curves of proper radius.

When the line is intended to be straight make it so absolutely.

Curves.—Where curves are required, make them as flat as possible, and on a first-class road where long trucks or loads are liable to come, only in extreme cases should it exceed a curve of 50 feet radius.

Minimum Radius to Curve.—On mountainous roads it sometimes becomes necessary to increase the curve to a radius of 20 feet.

Heavy Traffic vs. Passenger Service.—In discussing the question of permissible grades, it will, perhaps, be best to consider the roadways as being used for two specific purposes, one, where heavy traffic has to be provided for, and the other where passenger service is of the greatest importance, or, as it might be designated, loads *vs.* time. In a general way it may be said that when the conditions neces-

sary for the first are complied with, the second are met equally well.

To Determine Grades.—To determine what grades can be allowed, it becomes necessary to see what difference in results are caused by a difference in inclination.

Reduction of Draught by Increase of Inclination.—A man can walk up a slope of 100 in 120, and a horse or mule can ascend an incline of 100 in 175, and it has been found by experiment that a horse pulling his maximum load on a level, can pull but $\frac{1}{5}$ as much if the slope is made 1 in 50, and this gradually lessens until with a slope of 1 in 10 he can draw but $\frac{1}{4}$ as much as his level load, or to make it more complete, see the following table made from experiments by Gayffier* and Parnell† upon French and English roads, the results of the latter being the average of three velocities, calling the load which a horse can draw on a level 100.

Experiments of Gayffier and Parnell.

On a rise of	1	in	100	a horse can draw only	.....		.90*
"	"	1	" 50	"	"	"	..... .81*
"	"	1	" 40	"	"	"	..... .72†
"	"	1	" 30	"	"	"	. ..... .64†
"	"	1	" 26	"	"	"	..... .54†
"	"	1	" 20	"	"	"	..... .40†
"	"	1	" 10	"	"	"	..... .25*

Experiments of Sir Henry Parnell to find Draught Required.—And as the capacity for draught is limited by the steepest grade, no slope should be allowed up which a fair load cannot be drawn. The experiments of Sir Henry Parnell show that to draw a stage coach over the same

road, having different degrees of inclination, the following results were obtained:

FORCE OF DRAUGHT REQUIRED.—LEVEL ROAD CALLED 100.

Inclination.	At 6 Miles per Hour.	At 8 Miles per Hour.	At 10 Miles per Hour.
1 in 20	268	296	318
1 " 26	213	219	225
1 " 30	165	196	200
1 " 40	100	166	172
1 "600	111	120	128

No Counter Grades to be Allowed.—In laying out a road, with regard to grades, have a continuous inclination in one direction, and do not allow any counter grades for, in ascending, each foot descended on a counter grade means just so much more rise to be overcome.

Divide Roads in Classes According to Grades.—Different writers have proposed to divide the roads into classes, and limit the grade for each class. In some cases the grades are fixed by law.

The maximum grade established by the French Government Board of Engineers is 1 in 20*. The Holyhead Road in Wales uses 1 in 30 as a maximum, except in two cases. The road over the Simplon Pass averages 1.22 on Italian side, and 1 to 17 on Swiss side, with one case of 1 to 13, and in this State several turnpike roads are limited by law 1 in 11.

Herschel's Classification of Roads.—C. Herschel, M. A. S. C. E., in his prize Essay on the Science of Road-Mak-

* Gillespie's Roads and Railroads, p. 42.

ing,* proposes to divide in three classes—viz.: State, County and Town roads, and limit the inclinations, first, 3 to 5 in 100; second, 5 to 7 in 100, third, 7 to 10 in 100.

Prof. S. F. Miller † suggests making them of two classes, the first not to have a gradient of more than 1 in 20, and the second not to exceed 1 in 10.

Vertical Rise Equivalent to Lengthening Roads.—A vertical rise is equivalent to an increase in the length of the road proportional to the angle of inclination.

Equivalent Length of Level Road; Experiments of Sir John MacNeil.—The force expended in carrying a given load from any point to another at a higher elevation, is equal to the force of traction together with the force necessary to lift the load to the elevation attained. Experiments made by Sir John MacNeil show that a wagon loaded with six tons, drawn three miles per hour, upon a slope of 1 to 30, one mile is equivalent to 2.7 level miles, and for a stage coach weighing three tons, drawn six miles per hour, the equivalent level road for one mile is 1.62 miles.

On Long Incline Have First Portion Steepest.—Where a long incline becomes necessary it will be found economical to make the first portion the steepest, and decrease it as it ascends, and if the slope can be varied by occasional level stretches the efficiency of the road will be greatly increased.

The road-bed on steep slopes is subject to greater wear from the feet of horses in ascending, and is much more subject to serious erosion by heavy rains.

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*Report to Massachusetts State Board of Agriculture, 1869–1870.

† Massachusetts State Report, 1869–1870.

Minimum Grade.—Where the inclination of the road is not greater than 1 in 33 it will not pay to materially increase the length to reduce nearer to a level. So far, in treating grades they have been considered as obstacles to ascent, and we will further consider how they may be obstacles to descent.

Experiments of Sir Henry Parnell and Dr. Lardner on Angle of Repose.—On a descent the inclination should not exceed the angle of repose for a vehicle, which varies according to the road-bed, from 1 in 40 to 1 in 10. On a road with a slope just sufficient so that the force of gravity would overcome the friction, a loaded vehicle would descend with unaccelerated velocity and a considerable speed could safely be maintained in descending.

If the inclination is materially steeper than as shown above, so that a speed of only one-half or one-third as much can be safely maintained, it would be equally cheap to have a level road that was twice or three times as long.

To Ascertain Angle of Repose.—The angle of repose, for any given road-bed, can be easily ascertained from the draught upon a level, with the same character of surface; that is, if the force necessary, on a level, to overcome friction is $\frac{1}{30}$ of the load, then the same fraction expresses the angle of repose for that surface.

WIDTH OF ROADS.

The proper width of roads and road-beds are matters which ordinarily receive little attention. A road-bed is frequently constructed so wide as to add so much to the cost of maintenance as to render it impracticable to keep it in proper repair.

Revised Statutes of New York Fixing Width of Public Roads.—The revised Statutes of New York State require all public roads laid out by the Commissioners of Highways to be not less than three rods wide, and require "all roads that have been used as public highways for twenty years to be opened to *two rods at least.*"

English Roads.—In England turnpike roads are obliged by Statute to be laid out four rods wide, and 22 feet wide to be bedded with stone.

Roman Military Roads.—The Roman military roads were established 12 feet in width when straight, and 16 feet when crooked.

Classification by French Engineers.—French engineers make four classes of roads: First, 66, 22 stoned; second, 52, 20 stoned; third, 33, 16 stoned; fourth, 26, 16 stoned.

In England turnpike roads, near towns, are 60 feet wide, by-roads 20 feet wide.

Holyhead Road.—The width of the Holyhead Road varies from 32 feet where level to 22 feet in precipitous places.

Effect of Too Wide Roadway.—Where the roadway is too wide it usually results in no part being kept in good repair, while if it was narrowed the whole could be kept in first-class condition at less expense, and a well kept road of even 20-feet width is far preferable to a road but half maintained of double the width.

In laying out it may be advisable to take a strip considerably wider than the intended road-bed, so as to provide for possible contingencies in the future when the land becomes more valuable. *Lay out* sufficiently wide, but build only so much as can be kept in thorough repair.

These general rules about what should be done are all well enough in their way, but it will be found much more satisfactory in results to obtain the services of a competent engineer, and let him enter into the details involved in each particular case and decide from the conditions that arise.

The judgment and skill introduced in this way will frequently save costly and troublesome mistakes, and leaves nothing to chance or ignorance. (See Appendix 1.)

ROAD-BED.

Requirements of a Good Road-bed.—The essential requirements of a good road-bed are that it shall be practically unyielding—smooth on the surface, and impervious to water; and without these requirements there can be but little durability.

General Requisite for Road-beds.—Before calling attention to particular kinds of road-bed there are certain requisites applying to all kinds.

The first and most important of these is *thorough drainage.*

No matter what the material may be a proper attention given to drainage will be found to be a good investment, both as to first cost and future maintenance.

Advantages of Drainage.—Some of the advantages of thorough drainage will readily present themselves.

In this climate the worst enemies to building, or properly maintaining a road-bed, are water and frost, and if the first is kept out the second will have little or no effect, as the surface will not be affected, and heaving will be reduced to a minimum. Again, if a road-bed is thoroughly drained, it dries much more promptly, and has less mud and less dust

The construction of road-beds may be properly divided into two parts—viz.: the foundation and surface. Under the head of foundations is included all necessary sub-drainage works, culverts, ditches, etc.

Earth Roads.—For earth roads, as commonly built, there is but little to be said, and they should only be tolerated in a new country or where there is absolutely nothing but earth, of which to make a road.

Yet with earth alone a very passable road can be made and maintained, if sufficient care is taken to have it thoroughly drained, and the surface of proper shape.

The persistent care with which some of the so-called Road-Surveyors, in the country, excavate the material which has washed into the gutters and replace it upon the center of the road, seems to indicate a belief that the powers of man surpass and are superior to those of nature.

Cost of Handling Earth, etc.—Regarding the cost of handling earthwork of various kinds, many elaborate tables have been compiled of the cost, the distance to which it can be profitably cast with shovels, how far it can economically be carried in barrows, etc., all of which are of great value to an engineer in the determination of methods of conducting work, and the economy of management, but to the average individual who may be called upon to make or supervise the making of a road, they are but little better than so much Latin or Greek.

Handling Earth with Shovels, etc.—The generally accepted rules in handling earth, are: first, with shovels it can be cast horizontally from 5 to 10 feet, and vertically it can be lifted or thrown from 5 to 7 feet, and the cost of moving to the maximum distance either horizontally or vertically will be found to be nearly the same.

Wheelbarrows.—Where wheelbarrows are used, it will be found that they can be economically used up to a distance of perhaps 200 feet, but when it becomes necessary to carry to a greater distance than this, it will be better to use carts. Any increase in the inclination of the barrow road will have the effect to decrease the amount of material that can be handled, and an inclination of 1 in 10 will reduce the load that can be wheeled to two-thirds of what can be handled on a level road.

To overcome a vertical rise of 3 feet, will cost as much as wheeling from 80 to 100 feet horizontally.

Hauling with Carts.—With one-horse carts, it is estimated that one foot vertical costs as much as 14 feet horizontal.

Time Required for Dumping.—For a long haul it will be found that two-horse carts are much more economical than single carts; and dumping carts in every way preferable to the much used pole-bottomed carts or Studebaeker wagons employed in the vicinity of New York. A series of observations were made by the writer upon the relative time required to dump a load and get away, with the two kinds of carts.

The time was taken when the team was stopped on the dump, and when the driver started to drive away; and it was found that with the dump cart the average time for dumping and getting away was three-quarters of a minute, while with the other kind it averaged about three and one-half minutes.

Shrinkage of Earth.—In determining the amount necessary to make a specified embankment, the shrinkage of the material used should be carefully considered, as it will be

found to vary from 8 to 15 per cent., according to the nature of the material, gravel and sand shrinking the least and clay the most, the latter sometimes reaching 25 per cent.

Gillespie* gives an easy approximate rule for determining the cost of moving, with single carts, one cubic yard of earth any distance, on a level, deduced from the formulas of Ellwood Morris, C. E. (See *Journal of the Franklin Institute*, September, 1841.)

Gillespie's Rule for Cost of Moving Earth.

For	300	feet	÷	wages of cart and driver by	.....	24
"	500	"	"	"	.....	19
"	1,000	"	"	"	.....	12
"	1,500	"	"	"	.....	9
"	2,500	"	"	"	.....	6
"	3,000	"	"	"	.....	5

The proportional expense of carrying long distances will be found to be less than short distances, as less time is lost in filling and dumping.

Drainage.—Drainage for a road should be of two kinds, surface and sub-drainage. The first provides for the speedy removal of surface water or rain-fall on the surface, and the second for the removal of water which penetrates beneath the surface, and into the body of the road covering.

Effect of Perfect Sub-Drainage.—As a result of perfect sub-drainage, there is little or no effect from frost, and the surface and body of the road does not become softened and destroyed in summer.

*Roads and Railroads, p. 131.

Surface Drainage.—For surface drainage, ditches should be provided along each side of the road having sufficient fall to promptly carry away any water that reaches them. Where it becomes necessary to carry the water across the roadway culverts should be provided.

All drains should have a continuous fall throughout their entire length, and the size will depend upon the inclination and the amount of water they are expected to carry.

The amount of rain-fall over the area to be provided for is an important element in deciding upon the sizes required. For Central Park provision was made for a rain-fall of two inches per hour over the entire surface, but this is largely in excess of the usual requirements.

ROAD SURFACES.

Kinds of Road Surfaces.—These may be divided into Gravel, Macadam, Telford, and the pavements of various kinds, such as granite, wood, asphalt, brick, etc.

Gravel Roads.—In portions of the country where gravel is easily obtainable, a very satisfactory road can be made by making the surface for a greater or less depth of gravel.

Manner of Construction.—Prepare the foundation so as to allow for prompt drainage, and shape as the finished road is intended to be; make the sides of the road planes, and not curves, and then roll thoroughly to get a solid foundation.

Put on a layer of gravel from 6 inches to 8 inches in thickness, sprinkle thoroughly and roll till very compact and firm. Next spread another layer from 4 inches to 6 inches of gravel, and sprinkle and roll till the desired hardness and smoothness are obtained.

Use Binding Material if Necessary.—If the gravel has no binding material in it, a sufficient amount may be incorporated in the last layer to cause it to take a good bond.

Hard Pan and Bank Gravel.—Where it is possible to get blue gravel or hard pan and clean bank gravel, the two can be so mixed as to give a surface almost like concrete in hardness. When the two are used together a two-horse grooved roller for the first layer will be found very effective, and the material should be quite wet while rolling. The surface can then be finished with a steam roller, or with a smooth roller, sufficiently loaded to give the requisite weight.

Weight of Roller.—In completing the surface of a gravel, or other road, where rolling is required, the weight of the roller should be as much per inch as the weight per inch on the tire of the heaviest vehicles likely to pass over it. For ordinary traffic a very durable and economical surface can be produced in this way.

GRAVEL SURFACE WITH RUBBLE FOUNDATION.

Gravel and Rubble.—There are in the vicinity of New York City many very good examples of the above named road—viz.: in Central Park, also Avenue St. Nicholas from One Hundred and Tenth Street northward, and others.

Avenue St. Nicholas.—The method of constructing this latter road* will perhaps furnish as good an illustration as can be readily found.

On the prepared road-bed, which was made of the same shape as the finished surface, and well rolled, was placed rubble stone not exceeding 9 inches in the greatest dimen-

* See first Report of the Commissioners of Public Works.

sion, and most of them less. These stones were placed as uniform as possible and closely covered the surface. On top of this was placed a light layer of quarry chips which was then rolled with a 6½-ton roller till the spawls were well compacted and wedged into the interstices of the rubble foundation. On this was spread a light layer of gravelly earth or hard pan, moistened by sprinkling carts, and then rolled to fill all spaces.

The gravel was applied in two layers, all of the large stone raked out, and the whole kept moistened while rolling. Care was taken not to have it too wet.

The first layer was thoroughly rolled before applying the second.

Grant on Gravel Roads.—Before the roller was put on the top layer a light coat of gravelly loam or hard pan about one-fifth the bulk of the gravel was thoroughly mixed in, by raking, until well incorporated with the gravel. A thorough rolling completed the process, and the roller could be used occasionally to good advantage after the road was open to travel. W. H. Grant, M. A. S. C. E., who had an extensive experience in building gravel and Macadam roads, says, "It is believed that gravel roads, constructed with either rubble or Telford foundations, are better suited for light and pleasure travel, are more agreeable for carriages and horses, less difficult and expensive to maintain, require less attention in watering, and raise less dust than roads finished with Macadam surface."

Cross-Section of Roadway.—The top surface of all roads should have, in addition to the gradient, a side slope from the center, varying according to the hardness of the surface.

In a general way, whenever it is practicable, the side slope of the road should equal or exceed the longitudinal gradient, so that the water passing over the surface may take a course to reach the gutter not sharper than 45 degrees with the center line. In some of the smaller German States, where road-making and maintenance has been reduced to more of a science than with us, they allow the rise at the center from $\frac{1}{40}$ to $\frac{1}{60}$ of the width of the road.

Rise of Road-bed in Germany and Prussia.—In Prussia the side slope is prescribed and bears a certain relation to the gradients of the roads, varying from $\frac{1}{24}$ in roads falling more than 4 in 100, to 1 in 12 for roads falling less than 2 in 100.

MC ADAM SURFACE.

McAdam, from whom the road so called takes its name, maintained that the foundation of the road should not be of large stone at all, nor should it of necessity be of an unyielding nature, and he made the comparative cost of maintaining a road with a road-bed of solid rock and one having a soft soil or morass for foundation, as 7 to 5.

Size of Stone as Fixed by McAdam.—McAdam maintained strenuously that a stone over one inch in diameter was determined in a road, as it had a tendency to tip when a wheel came on it, and thus moved the adjacent material; he afterward substituted weight for size, and made 6 ounces the maximum stone that was to be used. He has a considerable following among the French and English engineers, but in this country the Telford foundation is generally preferred.

Parnell's Specifications.—The specifications for Telford, as given by Parnell's Treatise, London, 1833, give the fol-

lowing directions: Prepare the road-bed of the required shape, and on this set stones by hand, to form a close pavement. Set the stones carefully on their broadest edge, lengthwise across the road, the upper faces not to be more than 4 inches in breadth. Break off all irregularities with a hammer, and fill all interstices with stone chips, well rammed in between the larger pieces, to make a compact mass.

On this place a layer of stone as nearly cubical in form as practicable and about 2½ inches in diameter to a depth of 4 inches, and then 2 inches more to be added as a second layer, and finally the whole to be covered with 1½ inches of gravel, free from clay or earth.

Binding Material Detrimental.—Parnell says that *the presence of binding material* on a new road is a positive detriment, as it prevents solidity by getting between the stones. The custom to-day is much as he describes, excepting some improvements or modifications. Neither McAdam nor Telford used rollers.

The Use of Rollers.—The use of rollers in road-making, which is now considered a necessity, was brought prominently before English readers, by a paper written by Sir John Burgoyne, in 1843. He recommended as the greatest attainable weight 261 pounds per inch of roller. (See Appendix.)

There are three types of McAdam road, as given by him—traffic made, and horse and steam-rolled.

With a horse roller it is extremely difficult to compact hard stone without binding, and no steam roller is heavy enough to compact trap or granite without binding.

Horse vs. Steam Roller.—The horse roller will make a better road than can be made by traffic, but this is very

much inferior to a steam roller with the maximum weight per inch of roller.

Where the surface is rolled with a sufficiently heavy horse roller it is cut up badly by horses' feet, and then the admixture of manure and dirt prevents a thorough bonding and compacting of the surface.

The steam roller, in addition to being heavier, does not cut up the surface and allows a harder binding to be used, and the action of the roll has a tendency to arrange the stone more compactly than would be done by weight alone.

Southern Boulevard.—About New York City are many good examples of Telford and Macadam pavement, and considering the service rendered, none perhaps more worthy of mention than the Southern Boulevard constructed by W. E. Worthen, M. A. S. C. E., commencing at Third Avenue and running easterly and northerly from the north side of Harlem River through the annexed district.

Manner of Building.—In constructing it, the earth was first rolled thoroughly, and then two layers of 2½-inch trap rock, the first 6 inches in thickness and the last 4 inches in thickness, placed upon it; these were thoroughly rolled with a 2-horse roller, and then 2½ inches of screening were spread over the surface and well rolled.

The screenings were applied very wet. The road had a very steady, and much of it heavy, traffic, yet it remained in very good condition for quite a number of years with trifling repairs.

As long as the surface of a roadway of this kind remains unbroken it stands very well; but, as is the case at present with the Southern Boulevard, it has been partially excavated to make place for a railroad, and the material has

never been gotten back as compactly as before, and the road has been badly used up.

Road Built by E. P. North, M. A. S. C. E.—A road built by E. P. North, M. A. S. C. E., was composed of 2-inch stones in layers 6 inches in thickness, rolled with a roller 6 feet in length, weighing two tons when unloaded and three and a-half tons with a load, and drawn by four or six horses.

Special attention was paid to get the stone as free from dirt, etc., as possible, and for this purpose it was handled with ten-tined forks, which allowed most of the finer portion to drop through, thus leaving the stone clean. The layers were thoroughly rolled, and then the dust and small stones were spread and rolled in, and finally about ¾-inch of clayey earth was spread on top and the whole thoroughly rolled, the roller passing 144 times over the surface. The roller used weighed from 75 to 100 pounds per inch of roll, but he considers them too light to be economical. (See Appendix, 2.)

The Glasgow and Carlisle Road.—The Glasgow and Carlisle Road was built with the roadway 18 feet in width and a crown of 4 inches in the center.

Metaling was put on the road in two layers. The bottom course was 7 inches in depth, placed with the broad end down and the top surface not over 3 inches in diameter; the bottom stones were carefully placed, breaking joints as far as possible, then the top spaces were filled with smaller stones packed in by hand and securely wedged.

The top layer was composed of stone broken to pass through a 2½-inch ring, spread and thoroughly compacted, and then covered with one inch of gravel. There was a drain from the bottom course every hundred yards. The

drains were carried clear across the road and into water courses at the outside.

After this road was completed and in use for a while, it was found that the repairs necessary required from 80 to 120 cubic yards of material per annum per mile.

Mc Adam Center on Earth Roads.—In constructing roadways having a portion only macadamized it will be found of great benefit in rolling to lap the roller on to the edge of the earth portion and thus compact the earth so as to give a suitable shoulder to help hold the metaling, then continue the rolling toward the center.

Thickness of Roads.—The thickness necessary for a good road-bed is given differently by different authorities. McAdam advocated 7 to 10 inches and considered the last ample for any service, but the custom in this country for heavy traffic is to make the thickness not less than 12 inches, though some roads have been built in Bridgeport, Conn., which have been made considerably less in thickness, and so far have reflected great credit upon the engineer in charge, by their thorough construction.

Where the traffic is so heavy that Macadam or Telford are not economical, it becomes necessary to use some kind of pavement.

The more common kinds are granite or trap-block, wood, brick, and asphalt.

GRANITE OR TRAP-BLOCK PAVEMENT.

These blocks, with various modifications for foundations, constitute the principal pavement in this country for exceedingly heavy traffic, and are durable, fairly smooth, and easily laid.

Size of Stones.—The general requirements for the laying of pavements in New York City are—the stones may vary from 7 to 9 inches in depth, 8 to 12 inches in length, and from $3\frac{1}{2}$ to $4\frac{1}{2}$ inches in thickness, and nearly rectangular in shape.

The road-bed is prepared by excavating to a depth sufficient to give a good sand bed, usually from 3 to 5 inches in thickness.

The sand must be clean and sharp, without too large an admixture of large stone, that is one inch or over.

The preparation of the road-bed must be made without plowing, and it is thoroughly rolled, if required, with a steam roller weighing not less than ten tons.

After the road-bed is prepared, the sand is placed thereon, and bond stones set at the proper places, giving a crown of 6 to 8 inches to the roadway, according to the width. The blocks are laid at right angles to the street, allowing 1 inch joint. The whole surface is then covered with sand, which is swept into the joints as the work progresses.

Ramming.—The rammers follow after, and with pinch bars adjust the stones to give fair and even joints, and then ram thoroughly, after which the sand is again strewn over the surface, and brushed into the joints. (See Appendix.)

Various Foundations.—Different foundations are sometimes used, such as concrete, etc., and the joints run full of cement or mastic of some kind; the latter method makes a surface practically impervious to water, and wears very satisfactorily.

Where a sufficiently rigid system of inspection, over opening the streets for connections with water, gas or steam

pipes, and sewers is maintained, this block pavement stands the heaviest traffic as well as anything in use.

WOODEN PAVEMENT.

Wooden pavement has been tried quite extensively in the different cities of this country, but so far have not proved an unqualified success.

Advantages.—The advantages of a wooden pavement are slight resistance to draught, noiselessness, easily cleaned—they cause less wear and tear on vehicles—are pleasant to ride over, and the first cost is less than stone blocks.

Objections.—The objections are slipperiness in wet weather, non-durability, both from wear and decay, and there have been found serious objections to them on sanitary grounds. Still where the foundations are properly made and drained, and the block treated so as to prevent rapid decay by any of the various processes, and especially where stone blocks are not easily available, they have proven a very satisfactory improvement in the character of the roadway.

Manner of Laying.—The various methods of laying will only be outlined, and a reference to the requirements for laying on the Strand, in London, will perhaps give the most modern and satisfactory practice.

Requirements for the Strand Pavement in London.—The excavation for the roadway is carried to a depth of 15 inches and a layer of Portland cement concrete 9 inches in thickness placed thereon and shaped to conform to the finished surface of the road. Concrete is composed of seven parts of stone, etc., to one barrel of cement. The top is floated on to the required shape and then the blocks,

of best Baltic redwood, or equally good timber, creosoted and placed endwise upon the concrete.

The joints between the blocks are then run with cement grout or hot bituminous mastic. Cement grout is composed of one part cement and three parts sand. The top of the pavement is then covered with a layer of sand or gravel and opened to traffic. (See Appendix.)

BRICK PAVEMENT.

In certain portions of this country brick has been used as a pavement and found to answer the requirements fairly well.

Brick Pavement in Des Moines, Iowa.—In Des Moines, Iowa, there are about ten miles of streets paved with this material, and they are proving quite satisfactory.

The method of laying is to surface the road according to plan, then to roll with a roller weighing 150 pounds to the inch, or ram with rammers weighing 81 pounds.

In embankment the layers are made 9 inches in thickness and thoroughly rolled or rammed. On the foundation as prepared is spread a layer of sand 3 inches in thickness, and on this the bricks, which are specially burned for the purpose, are laid flat, breaking joints in the laying. The joints are completely filled with sand and on top a course of sand 1 inch thick is spread.

The next course of brick is laid on edge, and the joints thoroughly filled with sand, then 1 inch of sand is spread over the top and it is ready for traffic. Brick used for the same purpose have been used in West Virginia and have proven satisfactory.

ASPHALT PAVEMENT.

Until quite recently asphalt has been used but little as a pavement for roadways in this country, and the climatic conditions are so different from France and England that at present it is a little problematical just how far, and under what conditions, it will prove successful when used alone.

Many of the pavements laid with it in Paris and London have proven very satisfactory, and some work has been done with the pavement in this country; but with the extremes of temperature from 10 degrees to 110 degrees in this climate, it will give the pavement a very severe trial, unlike anything it is called upon to undergo in either England or France.

Some of the pavement already laid in this country has seemed to prove fairly satisfactory, as in Boston and in Washington, but in many cases, under a severe traffic, it has been found wanting.

When used in combination with other material it has proven a very valuable adjunct; but with the limited information available and the comparatively short time it has been in use, the writer is not prepared to give an unqualified indorsement to its use in this country, or at least in this portion of it.

Constant Attention Required to Keep Surface in Good Condition.—Having obtained a smooth, properly compacted surface on a road, it should always thereafter be maintained in first-class condition; but it will be found that this can only be done by constant vigilance and attention.

Repairing roads is not unlike a fire just starting—a very little properly directed effort will stop it; and with great

force it applies to a road when the surface begins to get in bad condition.

In speaking of repairing roads we shall confine our attention to roads having an earth, gravel, or macadam surface, as repairs on pavements need no description here.

On earth or gravel roads a very effective and economical instrument to help keep the surface in condition, is what is described by E. P. North, M. A. S. C. E. (see Trans. A. S. C. E., May 1879), as a hone.

The Hone or Scraper.—This is made of various shapes and sizes, but in a general way consists of a timber, or heavy plank, faced on one side with a steel plate to prevent rapid wear, and provided with handles on the back to guide it, when being drawn along the road surface. It is attached to the team in such a manner as to draw at an angle with the line of the road, and is very effective in filling ruts, and removing small stones from the surface of the roadway.

This is best used while the road is somewhat softened by rain.

To Keep a Road in Good Condition.—To keep a road in good condition there should be no ruts; and to prevent ruts, it becomes necessary to prevent any accumulation of mud or dust.

If ruts are formed water collects, and the adjoining material becomes softened and more easily cut up and the drainage much increased.

Secret of Successful Road Repairs.—Here we have the secret of successful road repairs—viz.: *continual* repairs. Keep the dust swept from the road, the ruts filled up with suitable material, and the surface of the road will keep in good order.

If repairs are not continually made there can be no constant good road.

Sprinkle During Dry Weather.—When a long continued dry spell occurs it will be found economical as well as effective, in preventing excessive wear on a road, to sprinkle frequently.

Tresaquet, a French engineer, was the first to call attention to the continuous system of repairs, and it was adopted in Baden in 1845, and it has extended over nearly all European countries.

Amount of Material and Cost in Baden, 1845–1860.—In tables giving the amount of material used in making repairs previous to 1845, and subsequent to that time, it was shown that in 1832, 218.6 cubic yards of material were used per mile for repairs, while from 1855 to 1860 there was only about 90 cubic yards per mile required, and the cost of maintenance was reduced during the same period about 40 per cent.

Statements of French Engineers.—The statements of Gen. John F. Burgoyne, taken from the reports of French engineers, show equally good results from the continuous method of repairing, giving better roads at a reduction in the cost of maintenance of from 12 to 40 per cent. At the time these statements were made French engineers calculated that by maintaining the roads in the best possible condition, the cost of draught of merchandise over the roads in France might be reduced one-third, or about $30,000,000 saved to the public in one year.

Repairing on the Continuous System.—The method of repairing roads on the continuous system can be briefly outlined as follows :

Have the material for road covering deposited at convenient intervals along the side of the road, from 200 to 300 feet apart. Have a man detailed to look after the repairs of the road for every two or three miles, and let his sole duty be to keep his section in repair. The tools necessary for him to have will be a broom, hoe, shovel, rammer, wheelbarrow and water pot.

Duties.—He should keep all dust swept from the road in dry weather, remove all mud in wet weather, see that the surface drainage is maintained, and if there is any standing water on the road sweep it off and fill up the depressions. The covering which wears off should be replaced gradually, and the best time to replace metaling is during wet weather. Where there are ruts they should be thoroughly swept out to free from dust or mud, and then filled up with the prepared material.

Repairing.—If large breaks take place they should be brought up gradually, especial care being taken not to produce surfaces which will be avoided by the vehicles passing over, and proper attention should be given to make the new work bind to the old as promptly and completely as possible. The quantity of Macadam necessary to keep a road in proper condition varies according to the traffic and the quality of the material used, but the following table gives perhaps as fair an estimate as any.

Amount of Material Needed for Repairs.—The table is calculated for a roadway 20 feet wide and 100 feet in length, and gives the amount necessary to keep in repair for one year:

(1) Good material and heavy travel, 5.5 to 7.5 cubic yards.
(2) Medium material and heavy travel, 7.5 to 9.2 cubic yards.

(3) Poor material and heavy travel, 9.2 to 10.2 cubic yards.
(4) Good material and average travel, 3.7 to 5.5 cubic yards.
(5) Medium material and average travel, 5.5 to 7.5 cubic yards.
(6) Poor material and average travel, 7.5 to 9.2 cubic yards.
(7) Good material and light travel, 1.8 to 3.7 cubic yards.
(8) Medium material and light travel, 3.7 to 5.5 cubic yards.
(9) Poor material and light travel, 5.5 to 7.6 cubic yards.

Where it is not convenient to divide the care of the road in short sections, it will be found that a road roller, in connection with the maintenance, will be both profitable and satisfactory.

Use of Roller After Frost Comes Out of Ground.—In the spring, after the frost is well out of the ground, the whole surface of the roadway should be rolled with a heavy roller, preferably with a steam roller of maximum weight.

Use of Roller Considered Profitable.—In the opinion of the writer, there is nothing that gives more satisfactory returns for the amount invested, either in making or maintaining a road, than the free application of a heavy roller to the surface.

Uniform System of Construction and Maintenance Desirable.—For the most efficient and economical maintenance of the public roads, it would seem to be essential that a uniform system of construction and maintenance be carried out through the whole State or country. Create a State or National department to have general charge of all public roads and bridges.

Executive Officers and Division of the Work.—The head of the department should be a man of large experience, good executive ability, and thoroughly conversant with the art of road building. His duties should be to arrange and

direct the carrying out of all details relative to the construction and repairs.

For convenience, the State should be divided into districts and sub-districts, with a competent civil engineer in charge of each district, and assistants in charge of each sub-district, who, in their turn, have control of a certain gang or working force, and who must supervise the details of all construction and repairs for their respective districts.

Expensive Machinery Made Available.—Under a general system, stone crushers, steam rollers, and other expensive machinery might be employed such as towns would not be able to command.

Suitable material could in this way be prepared wherever found without regard to town lines.

Two Methods of Doing the Work.—Either of two methods could be adopted for doing the work: by men stationed singly, as previously mentioned, or by gangs working together, assigned to districts of such extent as they can thoroughly keep in repair.

Advantages of the System.—By substituting this or some similar method of managing the repairs on the roads, in place of the present unsatisfactory and expensive custom, we should undoubtedly be able, in a short time, to produce a permanent and noticeable improvement in the character of our roads, with the most economical expenditure of time and money.

It would also establish a system of individual accountability which would be a great help to keep up the morale of the force employed, for each one would be directly responsible to some one in authority over him, and any dereliction in duty could be easily detected and punished.

With the presentation of the foregoing we will leave the subject of maintenance of roads, firmly believing that if there could once be a system in successful operation to produce good roads, it would matter but little after that what cost was involved in the making of the roads, or what skill was necessary to maintain them; a grateful public would gladly pay the necessary taxes to do both.

From this we will proceed to suggest some of the advantages of good roads.

ADVANTAGES OF GOOD ROADS.

Let us look at some of the advantages to a community resulting from good roads.

Economic Considerations.—First let us look at it from an economic standpoint, as that is the position which strikes most people promptly and forcibly.

It has been determined by careful experiments that two or three times as great a load can be drawn on a broken-stone road as on gravel, and four or five times as much on a good pavement of rectangular stones.

Experiments of MacNeil.—Very many experiments have been made to determine the actual force required to draw a given load over different surfaces or pavements, and Sir John MacNeil, in his experiments, determined that the traction for a load of one ton for different surfaces was as follows:

1. On good pavement the force necessary to move the load was 33 pounds.
2. Broken stone on old flint road, 65 pounds.
3. Gravel road, 147 pounds.
4. Broken stone on rough pavement bottom, 46 pounds.
5. Broken stone on bottom of béton 46 pounds.

Many experiments have been made on the force required, mostly by English and French engineers, and the experiments have left but little to be desired.

The most concise and complete compilation of these different results with which the writer is acquainted, is that made by Rudolph Hering, Mem. Am. Soc. C. E., and read before the Engineers' Club in Philadelphia, in March, 1882, and recently printed in *The Engineering Record.* (See Appendix.)

Roads being the only means of communication with railroads and markets, it follows that if a heavier load can be drawn, and better time made on a good road than on a poor one, that the area benefited by railroads and made tributary to markets is increased in direct proportion to the goodness of common roads.

Good Roads Shorten Distances and Save Wear and Tear, etc.—It will readily appear that a farm four or five miles from market, on a good road, is virtually nearer to the market than one located but two or three miles away, but located on a poor road. It is estimated that a saving of as much as 25 per cent. in animal power alone can be saved by the improvement of the roadway, besides the saving in time, and the wear and tear on vehicles.

An eminent writer says : "The road is that physical sign or symbol by which you will best understand any age or people. If they have no roads they are savages, for the road is the creation of man and the type of civilized society."

The Best Roads.—The best roads in the world to-day are those of England, France and Germany, and their excellence is largely due to the fact that in each country they

came under *national* supervision, and the resulting highways, the finest in existence, are the cheapest to maintain, and in every way the most satisfactory to those who use them.

American Roads.—"The American roads are far below the average; they are among the worst in the civilized world and always have been, largely as a result of allowing local circumstances to determine the location. No general system of building or maintaining, and haste, waste and ignorance in building." To summarize the advantages of good roads:

They attract population, increase the value of property, decrease the cost of transportation, and thus encourage the greater exchange of products between one section and another; and being feeders for the railroads, they directly bring distant places more nearly together, and promote intercourse and the development of commercial life.

The writer has been compelled in looking for the results of elaborate experiments to gather them from foreign sources—that is, he has not been able to find any records of any extensive or continuous investigations upon traction, friction and kindred subjects made in this country.

He has availed himself liberally of the investigations and writings of such men as Gillespie, Gilmore, Herschel, North, Owens and others.

APPENDIX.

(1) Two forcible examples of the improvement that can be made, by careful engineering skill, in the chance location of roads are given in Gillespie's Roads and Railroads. (See pages 36 and 233.)

An old road in Anglesea, laid out in violation of this rule (to have no counter grades), rose and fell between its extremities, 24 miles apart, a total perpendicular amount of 3,540 feet; while a new road laid out by Telford between the same points, rose and fell only 2,257 feet; so that 1,283 feet of perpendicular height is now done away with, which every horse passing over the road had previously been obliged to ascend and descend with its load. The new road is besides more than two miles shorter.

(2) A more modern exemplification of the true principles of road-making are furnished in the construction of a plank road between Chittenango and Cazenovia, N. Y., under the supervision of Mr. Geddes.

Both villages are situated on Chittenango Creek, the latter being 800 feet higher than the former.

The most level common road between these villages rises more than 1,200 feet in going from Chittenango to Cazenovia, and rises 400 feet in going from Cazenovia to Chittenango, in spite of the latter place being 800 feet lower.

The line of the plank road, however, by following the creek, ascends only the necessary 800 feet in one direction and has no ascents in the other, with two or three trifling exceptions, allowed in order to save expense.

Rollers.—It is perhaps superfluous to give any description of the different kinds of rollers in use, but being desirous of calling attention to one mentioned by C. Herschel in Report of Massachusetts State Board of Agriculture, 1869–1870, I will briefly suggest rather than describe them.

The roller described and also delineated, is hollow, of cast iron, and so constructed as to be filled with water when

additional weight is required, which can be emptied when going from place to place.

A circular cast-iron frame surrounds the roll and carries the axle bearings. The outside of this frame is turned to form a groove, in which a strong wrought-iron band is fitted in a manner to turn easily. The wrought-iron band is made in two parts, and when put together incloses the pole on one side of the roll and the balance weight on the other side on an extension bar. This ring is arranged so as to turn on the frame, when it is desired to go in the opposite direction. Allowing the ring to turn instead of turning the roll saves much wear and tear on certain parts of the road. A roller of this kind, 4½ diameter and 3½ feet long, weighing 4 tons empty, would cost $560 to $600, and a larger size from $700 to $750. It originated in Chemnitz, Germany.

The ordinary, smooth cast-iron roller for use on the farm is of but little use on the road on account of its lightness.

The grooved iron roller, formed of two sets of rolls, one about 8 inches less in diameter than the other, is a very effective implement in constructing banks, or rolling the lower layer for a gravel road, but is unsuitable for use on the surface.

The steam roller is the most thorough and satisfactory machine, and is much to be preferred over any other kinds. They are made of various weights, some of those in France weighing as much as 440 pounds to the inch of roll. They cost from $4,000 to $7,000, and cost about $10 per day to run them.

Appended find the general form of specifications used in New York City for block pavement.

EXCAVATION FOR FOUNDATION.

Excavation.—(*a*) The roadway shall be carefully excavated where necessary and brought to the required pavement sub-grade, and all superfluous and extraneous matter removed.

Rock and Masonry Taken out Below Sub-grade.—(*b*) Any rock or masonry which is above the pavement sub-grade shall be removed to a depth of one foot below the same.

Sub-grade.—(*c*) Pavement sub-grade shall be uniformly one foot and one-tenth below the intended pavement surface. The foundation shall nowhere rise above said sub-grade. If it should fall below, owing to shrinkage, or on account of removal of rock or masonry, or other cause, no new filling shall be added other than sand of the same quality as that used for bedding the paving stones.

No Plowing Allowed.—(*d*) In the excavation below grade and preparation of foundation no plowing will be allowed.

Preparation of Foundation.—(*e*) The foundation shall be carefully brought to an even surface, conforming to the required sub-grade, and should there be any spongy material or vegetable matter in the bed thus prepared, it shall be removed and the space filled with clean sand carefully rammed so as to make such filling compact and solid, and when required by the engineer, the entire road-bed, after having been brought to the required sub-grade, shall be rolled with a steam roller weighing not less than ten tons, until the surface is firm and compact, to the satisfaction of the engineer.

When the steam roller cannot reach every part of the road-bed, the bottom at those portions shall be tamped or rolled with a small roller and sprinkled with water if required; and should the material of the bottom not admit of satisfactory rolling, such material must be removed and proper material substituted by the contractor at his own expense.

Price for Paving to Cover Excavation, etc.—(*f*) The cost of all excavation of whatever character required in executing the work shall be included in the price paid for the pavement.

BLOCK PAVEMENT.

Quality and Dimensions of Stone Block.—(*a*) The stone blocks are to be of a durable, sound and uniform quality of trap-block, each measuring on the face or upper surface not less than 8 inches nor more than 1 foot in length, and not less than 3 inches nor more than 4 inches in width, and not less than 7 inches nor more than 9 inches in depth; to be split and dressed so as to form, when laid, close end joints, and side joints not exceeding 1 inch wide top and bottom, with fair and true surfaces on top, bottom and ends; and are in all respects to be equal to the specimen blocks deposited at the office of the engineer, as hereafter provided.

Sample Blocks.—(*b*) Before any paving blocks are placed upon any part of the work, the engineer shall approve of the quality and finish of samples of the same, which shall be furnished at his office by the contractor.

When Stone Blocks May be Hauled on Line of Work.—(*c*) After any portion or portions of the street or avenue, not less, each, than the distance between two intersecting streets, shall have been brought to the required grade and the curb-stones set and crosswalks laid, and not until then (unless permission in writing is given by the engineer), the contractor shall haul upon the line of the work at each of said points a sufficient quantity of stone blocks to pave such portions.

To be Carefully Culled.—(*d*) The stones will be carefully inspected after they are brought on the line of the work, and all blocks which, in quality and dimensions, do not conform strictly to these specifications will be rejected, and must be immediately removed from the line of the work. The contractor will be required to furnish such laborers as may be necessary to aid the inspector or inspectors in the examination and culling of the blocks; and in case the contractor shall neglect or refuse so to do, such laborers as in the opinion of the Commissioners of the Department of Public Parks as may be necessary will be employed by said Commissioners, and the expense incurred by them will be deducted and paid out of any money then due, or which

may thereafter grow due, to the said contractor under this agreement.

Rejected Materials to be Forthwith Removed.—(*e*) After inspection, as provided above, all rejected stones shall be immediately removed by the contractor from the line of the work. The contractor will then be required to pile such stones as may have been approved, neatly on the front of the sidewalk, and not within three feet of any fire-hydrant, and in such manner as will preserve sufficient passage-way on the line of the sidewalks, and also permit of free access from the roadway to each house on the line of the street. *After this inspection has been made, and after all the rejected stones shall have been removed entirely from the line of the work, and the accepted stones piled in the manner aforesaid, and not until each of these conditions shall have been faithfully fulfilled will the contractor be permitted to proceed with the preparation of the road-bed for the new pavement.*

(*f*) It being expressly understood that the work is to be prosecuted in sections of not less than the space between any two intersecting streets, and when the blocks are over 300 feet in length, then in sections not less than 150 feet nor more than 300 feet, and that these provisions relative to the hauling, inspection and removal and piling of stones shall apply to the work on each of said sections on the whole line of work.

Over Rail Ties and Other Places.—(*g*) Between, in, and one foot outside of railroad tracks, over vaults, around sewer, man-holes, frames, and in such other places as the engineer may deem proper, the contractor shall use for the pavement stone blocks of such lesser dimensions as the said engineer shall direct, but the same general dimensions on the top surface shall be maintained.

Laying the Pavements, etc.—(*h*) The stone blocks are to be laid at right angles with the line of the avenue, except at intersecting streets and in other special cases, when they shall be laid at such angles as directed, with such crown and at such grade as the engineer may direct; each course of blocks shall be of uniform

width and depth, and so laid that all longitudinal joints shall be broken by a lap of at least two inches, and that all such joints shall be as close as possible.

Ramming.—As the blocks are laid they shall be covered with clean, fine sand, which shall be raked until all the joints become filled therewith; the blocks shall then be thoroughly rammed to a firm, unyielding bed, with a uniform surface, to conform to the grade and crown of the street. No ramming shall be done within 25 feet of the face of the work that is being laid, and in doing all ramming the contractor shall employ one rammer to every two pavers.

Covering Sand.—Whenever the pavement for not less than 200 feet, and not exceeding 260 feet, shall have been constructed as above described, it shall be covered with a good and sufficient second coat of clean, sharp sand, and shall immediately thereafter be thoroughly rammed until the work is made solid and secure, and so on until the whole of the work embraced in this agreement shall have been well and faithfully completed, in accordance with these specifications.

Wooden Pavement on The Strand, London, England.—For the complete specifications from which the abstract in the body of the article was taken, see *The Engineering Record* for December 9, 1889.

Resistance to Traction on Roads.—Resistance to traction is very nearly proportional to the weight.

It increases on paved roads with the velocity, owing to the increase of concussions, but it remains nearly constant on roads with a compressible surface, as earth, sand or turf (Rumford & Morin). The smoother the pavement and the less rigid the carriage—*i. e.*, the better it is hung—the less does the velocity affect the resistance.

Whenever the velocity is not above a pace, springs do not affect the resistance; when it is greater, the resistance

decreases as the carriage is better hung. On soft roads springs may slightly increase the resistance at low speeds. The destruction of the road and carriage is greater when the latter is without than with springs (Morin).

The advantages of a paved over a Macadam road in point of traction, are considerable for heavy loads, less for stages, and nearly nothing for light carriages (Debaune).

According to Morin, the resistance to traction increases slightly with the number of wheels, but is inversely proportional to their diameter. According to Dupuit it is inversely as the square root, according to Clark, as the cube root of the diameter. The destruction of the road and the carriage is always greater as the diameter of the wheel is less (Morin).

On a paved or hard Macadam road the resistance is independent of the width of the tire, when this quantity exceeds about 4 inches (Dupuit and Morin). When it is between 2 and 4 inches for heavy loads and low speeds, the broader tire will give proportionately less resistance. For light loads the width has no influence on the resistance. On earth and other compressible roads the resistance increases inversely as the width of the tire (Rumford and Morin). In Europe a common rule is to make the width of a tire one-half an inch for every 125–175 pounds upon the wheel, according to the character of the roads. The least width is usually about 2 inches.

From the above we may gather that the most economical conditions for traction are:

1. A hard and smooth surface, both when speed is to be attained and where heavy loads are to be hauled, and

2. Large wheels, especially for heavy loads.

3. For light loads the width of tire is immaterial, and is therefore better as narrow as the character of the road will permit. For heavy loads the resistance increases inversely as the width of tire. While on hard roads this effect is less, it is very decided on soft roads. The width should not exceed 4 inches at least on hard roads, and it is rarely less than 2 inches, except for light pleasure carriages.

4. Easy springs not only act preservingly on roads and carriages, but materially decrease the resistance of traction at trotting or running speeds.

The following table presents the results of experiments on the resistance of vehicles to traction or different classes of roads. The fractions which are generally rounded off, indicate the part of the whole weight, which is equivalent to the resistance of drawing it on a level road. An examination of this table will clearly show the great economy in horse-power by using the hardest and smoothest roads. For instance, if one horse can just draw a load on a level road on iron rails, it will take $1\frac{2}{3}$ horses to draw it on asphalt, $3\frac{1}{3}$ on the best Belgian block pavement, 5 on the ordinary Belgian pavement, 7 on good cobble-stones, 13 on bad cobble-stones, 20 on an ordinary earth road, and 40 on a sandy road.

Character of Road.	Resistance in Terms of Load.	Velocity.	Authority.
Sand	$\frac{1}{3}$	Pace	Bevan
Sandy Road	$\frac{1}{15}$	3′ 12″ per sec	Morin
Loose Gravel	$\frac{1}{4}$	Pace	Bevan
Gravel, 4 inches thick	$\frac{1}{10}$	Pace	Morin
Common Gravel Road	$\frac{1}{16}$	Pace	MacNeil
Gravel Road	$\frac{1}{26}$	3′ per sec	Rumford
Gravel Road	$\frac{1}{28}$	12′ per sec	Rumford
Hard Rolled Gravel	$\frac{1}{30}$	Pace	Bevan Minard
Wet Turf	$\frac{1}{8}$	Pace	Morin
Hard and Dry Turf	$\frac{1}{18}$	Pace	Morin
Hard and Dry Turf	$\frac{1}{25}$	.....	Bevan
Ordinary Earth Road	$\frac{1}{10}$	Pace	Bevan
Hard Clay	$\frac{1}{30}$	.....	Bevan
Hard and Dry Earth Road	$\frac{1}{25}-\frac{1}{30}$	Pace	Morin
Ordinary Cobble-stone	$\frac{1}{8}$	Trot	.....
Ordinary Cobble-stone	$\frac{1}{16}$	Pace	.....
Good Cobble-stone (3½-inch)	$\frac{1}{16}$	Trot	Kossack
Good Cobble-stone (3½-inch)	$\frac{1}{30}$	Pace	Kossack
Good Carriage with Springs	$\frac{1}{25}$	Pace	Kossack
Macadam little used	$\frac{1}{16}-\frac{1}{25}$	.....	Morin
Bad Macadam	$\frac{1}{14}$	Pace	Gordon
Old Macadam	$\frac{1}{25}$	.....	Navier
Ordinary Macadam	$\frac{1}{25}$	Trot	MacNeil Perdon't Kossack
Ordinary Macadam	$\frac{1}{25}$	Pace	
Good Macadam (wet and slightly muddy)	$\frac{1}{50}-\frac{1}{54}$	.....	Morin
Best French Macadam	$\frac{1}{50}$	.....	Navier
Very hard and smooth Macadam	$\frac{1}{50}$	.....	MacNeil
Best Macadam	$\frac{1}{35}$	Trot	Rumford
Best Macadam	$\frac{1}{45}$	Pace	Rumford
Best Macadam	$\frac{1}{46}-\frac{1}{60}$	.....	Gordon
Best Macadam	$\frac{1}{48}-\frac{1}{70}$	.....	Morin
Ordinary Stone Block	$\frac{1}{25}$	.....	Perdon't Poncelet Minard
Ordinary Belgian Block	$\frac{1}{40}$	Pace	MacNeil

Character of Road.	Resistence in Terms of Load.	Velocity.	Authority.
Good Stone Block..... ..	$\frac{1}{17}$	Trot	Rumford
Good Stone Block.....	$\frac{1}{30}$	Pace	Rumford
Belgian Block, Boulevard, Paris....	$\frac{1}{45}-\frac{1}{66}$	.....	Navier
Good Belgian Block.....	$\frac{1}{30}$	Trot	Rumford
Good Belgian Block	$\frac{1}{60}$	Pace	Rumford
Good London Block.	$\frac{1}{63}$	.....	Gordon
Well-laid Belgian Block.....	$\frac{1}{65}$	.....	MacNeil
Good Belgian Block	$\frac{1}{45}-\frac{1}{87}$	....	Morin
Planked Roadway (bridge)..	$\frac{1}{40}-\frac{1}{57}$	.....	Morin
Asphalt.....	$\frac{1}{133}$	.....	Gordon
Granite Tramway.....	$\frac{1}{166}$	.....	Gordon
Iron Tramway....	$\frac{1}{300}$	.....	Gordon
Sleighs on snow, 3 inches thick, ¾-inch runners, temperature 26°.....	$\frac{1}{30}$	.....	.....

SECOND ESSAY.

ROAD CONSTRUCTION.

BY I. F. POPE ("BONA VIA, BONUM OPUS"), AUSTIN, TEXAS.

General Remarks.—The construction of country roads may be divided into three parts. 1. The alignment. 2. The earthwork, or formation of the road-bed. 3. The metaling, or formation of the hard road surface.

Width of Road.—Before, however, any of these can be undertaken, the width of the proposed road must be determined. Any excess width beyond the requirements of traffic is a waste of money. As two vehicles can conveniently pass one another in a width of 18 feet, the metaled or hard central surface should be made that breadth. Provision must also be made for foot passengers, and for a softer footing for horses during dry weather than the hard central surface. An earthen surface eight feet in width on each side of the central metal surface will answer both these purposes. The use of this less expensively constructed surface during dry weather will also be economical, as it will save the wear of the more costly metaled surface. For

all these reasons combined, the width of a country road should be as follows:

A central macadamized or metaled width of 18 feet, with earthen sides 8 feet broad on each side; or a total width for traffic of 34 feet, raised for drainage purposes (except where in cutting) not less than six inches above the level of the area it passes over. There should also be an earthen berm 8 feet broad on each side of the raised road for trees and for stacking the metal required for repairing the road. The total width of land, therefore, that should be reserved for road purposes, including the tree berms and side trenches, should not as a rule be under 66 feet, or 4 rods. Where high embankments are necessary, a greater width may be required. The following notes on road making will refer to a road of the width or dimensions just described.

THE ALIGNMENT.

Alignment of Road.—Having determined the points or places to be connected by a road, the country along the proposed line should be reconnoitered, and the general route of the road located by one or more reconnoissances. Great discernment is requisite in this preliminary alignment, so as to combine shortness of route with the avoidance of swamps that would entail an unreasonable cost in securing a good road-bed, and hills that might entail either steep gradients or heavy cost in deep cuttings. It should be remembered that in many cases it is of no greater length to go round a hill than to go over it, thus securing both greater economy of construction and easier gradients.

Location of Road.—The preliminary route being thus determined, it must now be surveyed with transit and level,

and the final alignment located along the selected line. It is of course expected that the person who undertakes the construction of a road has a thorough knowledge of the use of the transit and level, and the laying out of lines and curves and gradients.

Steepness of Gradients.—In laying out a road the gradients or longitudinal slope of the road should not be permitted, under ordinary circumstances, to exceed 3 feet vertical to 100 feet horizontal. Under exceptional circumstances 5 feet in 100 feet may be tolerated. A gradient steeper than 3 per cent. is an evil that should be avoided if it possibly can. In hilly country a gradient as steep as 5 per cent. is at times necessary, but endeavors should be made by judicious alignment to make the gradients as easy as possible. The powers of traction of a horse are much strained by gradients above 3 per cent. It would be far preferable, in many instances, to incur extra expenditure in keeping the gradient within this limit than to make the rate of ascent steeper, as the cost once incurred is incurred for all time; whereas, a steep gradient is forever a tax on the power of the draught animals, on the harness, and on the vehicles, and, in a short time, the loss due to this tax will greatly overbalance the saving effected by the steeper gradient. A young engineer may pride himself on the straightness of his road, but if this straightness is obtained at the expense of easy gradients, that might have been attained by slight deflections and curves here and there, his straightness and pride will prove very expensive to the traveling community that uses his road. Let it then be remembered that directness of route and easy gradients must both control the alignment of the road, and that any-

thing above 3 per cent. may be called steep; though, as I have said, in hilly country it may be necessary to go as high as 5 per cent. gradients.

On Road Gradients.—If the natural surface of the country through which the road passes has a natural rise or fall of less than 1½ per cent. the longitudinal run of the road surface may be kept parallel to this natural surface; though, at the same time, 6 inches above it. But if the natural surface of the country rises now and again above the grade of 1½ per cent. moderate cuttings and fillings up to 3 feet in depth or height may be resorted to if such will keep the gradients within the limit of 1½ per cent.; more especially if the cuttings will balance the fillings without an unreasonable length of haulage. At 3 per cent. grades the line of toleration should be drawn, and unless serious obstacles present themselves, such as would give an undue height of cutting or embankment, endeavors should be made, by judicious cuts and fills, not to exceed a 3 per cent. grade.

Gradients in Hilly Country.—In a hilly country, by going around a hill instead of over it, an easy gradient may at times be obtained without unduly increasing the length of the road, or it may be advisable to ascend the hill by a zigzag route, as represented by the capital letter S. But in whatever way it may be most advantageously done, the limit of gradient should not exceed 5 per cent. Easy gradients permit the full utilization of the traction powers of a horse, steep gradients detract from it. A gradient as high as 3 per cent. may be tolerated, when, as I have said, undue depth of cut or height of embankment will result; but gradients of 5 per cent. should only be permitted where

great extra cost or great extra length of road would result by adopting a lower gradient.

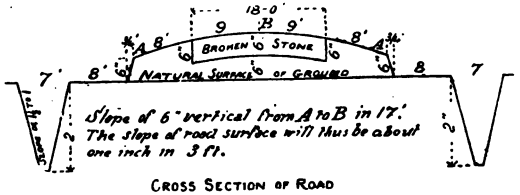
THE EARTHWORK OR FORMATION OF THE ROAD-BED.

Formation of Road-Bed.—The road being now aligned and its gradients fixed, the earthen surface or road-bed has now to be constructed. The width of this to be, as already stated, 34 feet.

Usefulness of Side Ditches.—Where the surface of the country has natural easy gradients, the road-bed should be raised six inches above it (as shown in the diagram), to keep the road dry. This raising of the road also effects the double object of forming a drainage ditch on each side to carry off the rain-fall to the nearest culvert or bridge. These ditches, from which the earth is excavated to form the raised road-bed, give an increased artificial height to the road to aid its subsoil drainage, and to prevent any tendency of its becoming sodden during a long continuance of wet weather.

Description of General Cross Section of Road in Embankment.—The cross section then of the earthen surface of the road, where it needs no action to improve on the natural easy gradient of the country, will be as follows,

Vertical scale of 2 feet, and horizontal scale of 12 feet to an inch.



CROSS SECTION OF ROAD

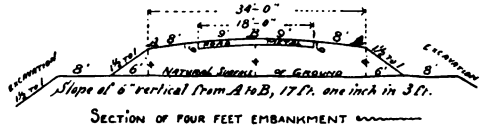
To obtain the earth for raising the road-bed as above, the side ditches will have to be dug 7 feet broad at top, 1 foot at bottom, and 2 feet deep, with side slopes of 1½ feet horizontal to 1 foot vertical. This size trench will take up the balance of the 66 feet reserved for road purposes. The side trenches, which appear rather deep, will soon silt up somewhat. In no case is the earth for raising the road to be taken from the 8 feet berm reserved for trees, as this will make these berms lower than the surrounding country. All the earth required for the road must be taken outside the 8 feet berm.

Road in Marshy Land.—In low, marshy land, the height of the road-bed should not be under 1½ feet above the water line.

Side Slopes of Embankments, How Graded.—Where embankments are necessary, the side slopes of these embankments, if in ordinary soil, must be in the proportion of 1½ feet horizontal to 1 foot vertical, as shown in the diagram. Thus, an embankment 3 feet high, would have its toe 4½ feet beyond the vertical line of the edge of the 34 feet road surface. If 6 feet high, the toe would be 9 feet beyond; and so on; always adding half the height to the total height to find the spread of the toe of the embankment. In constructing embankments, all large clods of earth should be broken up, as otherwise, where these accumulate, depressions or hollows will form in the road surface when the embankment settles.

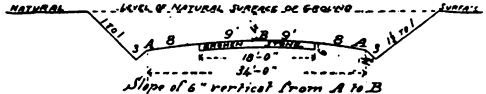
Extra Allowance for Settlement to be made in Constructing High Embankments.—An extra allowance of from one to two inches (according to the nature of the soil) per foot of height of embankment must be made while under con-

struction, so that when settlement occurs the embankment will have the full height originally intended, metal 6 inches thick.



SECTION OF FOUR FEET EMBANKMENT

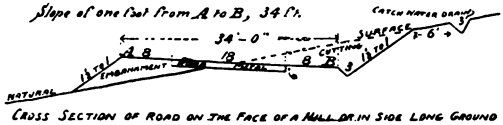
Road in Cutting.—Where the road, to obtain a proper gradient, is in cutting or excavated, the section of it will be as follows: The slope of the sides of the cutting to be according to the nature of the soil, from 1½ feet horizontal to 1 foot vertical in ordinary soil, to almost perpendicular when in rock. The side gutters to be 3 feet broad at top, and 1 to 1½ feet deep; with side slopes of 1½ horizontal to 1 vertical. If the cutting be of short length or in rock the gutters may be proportionately reduced in size.



SECTION OF ROAD IN FOUR FEET CUTTING, SHOWING TO THE LEFT WHERE THE SOIL WILL PERMIT A SLOPE OF ONE FOOT HORIZONTAL TO ONE FOOT VERTICAL, AND TO THE RIGHT WHERE ONE AND A HALF TO ONE IS NECESSARY.

Road Along Face of Hill.—Where the road is in sloping or sidelong ground, as when it runs along the face or side of a hill, the most economical form of construction is to have the cuts and fills of the cross-section to balance one another. To effect this more of the width of the road will be in cutting than in embankment, owing both to the gutter and to the contents of the embankment portion being of greater area than than of the cutting. The drainage slope of the road surface to be made towards the hill

side and the water thus not permitted to run over the edge of the embanked portion. The fall or slope of the road surface from the edge of the embankment to the gutter on the inner or hill side will be 1 foot. The gutter to be 3 feet wide at top and 1 foot deep, with side slopes of $1\frac{1}{2}$ to 1.



CROSS SECTION OF ROAD ON THE FACE OF A HILL OR IN SIDE LONG GROUND

Catch-water Drain.—In addition to the gutter on the inner side of the road another gutter or catch-water drain should be made on the upper side of the hill above the road and at least six feet from the edge of the cutting, to receive and carry off the drainage of the face of the hill above the road. These catch-water drains should be continued to the culverts that should be constructed wherever there is a necessity for cross-drainage, to relieve both the road gutter and catch-water drain from an accumulation of water.

DRAINAGE.

Drainage of Road.—The manner of draining the 66 feet or greater area, reserved for road purposes, should be under advisement at the same time as the grading of the road is under consideration. In fact, the forming of the road embankment may be said to be the same as forming the trenches for draining the area reserved for the road. The proper drainage of the area within the road reservation is

most important for securing a good road ; as all water permitted to lodge within this area will tend to sodden the road and render it incapable, unless by extra labor and expenditure, of bearing a heavily laden wagon. Trenches of sufficient depth and capacity should, therefore be formed to carry off all water from the road reservation to the nearest culvert or bridge. Those latter should be provided at all points where the cross-drainage of the country impinges on the line of road. It is in the long run cheaper to build a culvert to carry off this water than incur the expenditure that will be necessary to keep the road in good order where water is allowed to lie and soak into the road by capillary attraction. I have noticed the defective want of small culverts even on otherwise well-constructed railroads, causing the labor of frequently lifting the rails to bring the iron-way to a proper level ; this sinking being due to the softness of the earthen road-bed from the lodgement of water. The capacity of all culverts and bridges should be mathematically calculated to carry off all the water that impinges on the line of road. As instructions on the calculation of water-ways, and the designing of bridges and culverts, are outside the scope of this article, information on these should be obtained from treatises on these subjects. Any ordinary engineer by the use of a leveling instrument can give levels for the flow of water along a given line. The defective drainage of a road can consequently be only due to the want of knowledge of the value of efficient drainage to the well-being of a road.

THE METALING OR FORMATION OF A HARD ROAD SURFACE.

The Metaled Surface to be 18 *Feet Wide.*—As has been already stated an 18-foot width of metaling will suffice for

the requirements of traffic on a country road. In the immediate vicinity of a large city, that is, for a mile or two out, accommodation may be necessary for the simultaneous passage of three vehicles. In such case the metaled surface should be made 25 feet broad and the earthern sides each 10 feet.

The Telford System of Providing a Hard Road-bed.—There are two systems in use in the formation of a hard surface to meet the requirements of heavy traffic on country roads—viz.: the Telford and the Macadam. The former consists of a rough pavement of more or less large flat rocks, varying in thickness from 6 to 12 inches, as a foundation to receive an upper coat of broken stone, 6 inches to 12 inches in thickness, which forms the road surface.

The Macadam System.—The Macadam system dispenses altogether with the foundation of a rough pavement base, and places the broken stone, varying from 6 to 9 inches in thickness, immediately on the prepared earthen surface of the road. The Telford system may therefore be said to be the Macadam system with a foundation or hard base added. My own experience in India, in the Public Works Department of the Government, for whom I constructed over 400 miles of country road, and superintended the repair and maintenance at various times of over 1,500 miles of roads, is entirely in favor of the Macadam system, without the addition of a base. Where the method of constructing the earthen road-bed, as described by me, is properly carried out, the addition of a rock base under the macadamizing material is a useless waste of money. Where the road-bed is below the level of the country, and imperfectly drained,

the Telford system may be necessary; but with the efficient drainage advocated by me, and the manner of laying the metal or macadamizing matter carried out in the manner to be described hereafter, no base is necessary. It is more economical to expend a few hundred dollars per mile in securing efficient drainage in the original construction of a road than as many thousands in a rock base. I see that the Macadam system, in opposition to the double or Telford system, has also been introduced in America with good result by Mr. Pierce, of Bridgeport, Conn.

I am somewhat of the opinion of those who maintain that the broken stone or road surface material is more crushed and worn when between the hard, unyielding rock base below, and the heavy hammering weight of a horse and heavily laden wagon above, than where it rests on a more elastic earthen base, which is yet hard enough, by previous rolling with a 15-ton roller, to bear the weight of the traffic borne over it.

The material to be used to form the macadamized or metaled surface of the road will depend on what is locally obtainable suitable for such purpose. In some localities it is trap rock, in others limestone, etc. Again, on the prairie lands of Minnesota, Iowa, and parts of other States, there are no large masses of rock. In these gravel can be used as a substitute for stone. I have used broken stone, kunker, a formation of limestone found in large quantities in India, gravel, and even coarse sand when nothing better was procurable at a reasonable cost. I will describe, *seriatim*, the best method, as it appears to me, for consolidating all these (kunker excepted, which is not found in America), so as to form a hard surface suitable for traffic.

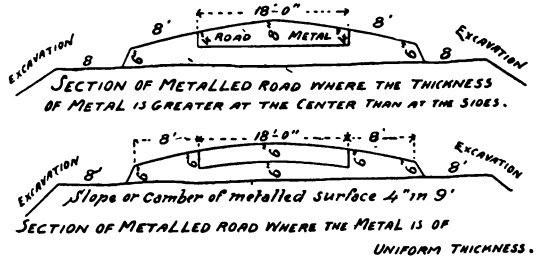
The Proper Thickness of Metaling.—It becomes now necessary to determine the thickness of metaling requisite to form the macadamized road surface. Various thicknesses have been used and have their advocates, of from 4 to 12 inches. The latter is, in my experience, excessive, and the former deficient. A 4-inch coat requires constant supervision and expenditure in repairs to keep heavy traffic from breaking through so thin a crust when in any way worn. More frequent renewals are also necessary, causing both inconvenience to traffic and extra expenditure in supervision, labor, and rolling to lay a fresh coat of material. From my experience, I would say, a golden mean between excess and deficiency is arrived at by making the thickness 7 inches when spread, reduced by consolidation to a little over 6 inches.

Broken Stone—Its Quality and Size.—The hardest stone or rock locally procurable, or obtainable elsewhere at a reasonable cost, to be selected to form the macadamized or metal surface of the road. This to be broken so that the pieces will pass through a ring $1\frac{3}{4}$ inches in diameter. This is the easiest and most practical way of testing the size of the pieces.

Slope of Cross Section of Metaled Surface, How Formed.—There are two methods in vogue in giving the requisite slope to the cross section of the metaled surface of the road to pass off the rainfall. In the one, the earthen surface is made level and the slope is given by a greater thickness of metaling at the center than at the sides. In the other the slope or camber is given to the earthen face, and the metal put on of one uniform thickness.

The Metal to be of Uniform Thickness.—The advocates of the first mentioned system say there is more wear at the

center than at the sides, and consequently the metaling should be thicker at the former. Those in favor of the uniform thickness say that as an equal pressure should be sustained by the earthen base under all the wheels, so the resistance (indicated by the thickness of metal) should also be equal, and that the extra wear at the center on a country road is inappreciable: the weight thrown by the inclined plane of the road on the lower side wheels compensating, in great measure, for the slight extra traffic at the center. My experience is in favor of a uniform thickness of metal; especially as it prolongs the time to a general renewal of the metaled surface, which has to be done sooner in the



ununiform system, as the sides are soon worn too thin for traffic, and it is difficult to bring them to the proper thickness without a general renewal of the whole cross sectional surface. The cross slope, or camber of the road, should therefore be given to the earthen base, and the metal spread on it of a uniform thickness.

Preparing the Earthen Surface to Receive the Metal.— While the broken stone metaling for the road is being prepared, the earthen surface or base should also be prepared to receive it. If possible, the earthwork of the road, where

in high embankment, should be exposed for a few months to the action of the rain-fall, which will tend to settle and consolidate it. Immediately before receiving the metaling, all hollows and depressions, etc., of the earthen road-bed, due to settlement or the action of the rain, should be filled up, and the earthen surface given the requisite camber or cross slope from the center to the sides, as shown in the diagram. The whole surface should then be rolled with a 15-ton steam road roller (all unevenness and derangement of shape due to the action of the roller being promptly made good), until the roller ceases to have any impression on it. If the surface be of sand, or of such nature as to move or heap up before the roller, a thin layer of broken stone or gravel should be strewn on it.

Stone Bench Marks.—The earthen surface being now thoroughly rolled, and formed to the proper curved camber, stone bench marks 8″x8″x4″ should be sunk at 50-feet intervals along the edges and center of the proposed line of metaling, and set in position by a leveling instrument to indicate both the height of the earthen surface and the base of the metaling, and for giving the proper camber to the road.

Gauging Height of Metaling. — Temporary wooden gauges 7 inches high to be placed over these bench marks, to show the height to which the metaling must be raised as it is placed on the road. The bench marks being placed exactly 50 feet apart can easily be found; and they will thereafter serve to indicate the depth of wear of the metaled surface. The cost of these bench marks will be small, as their sides need not be cut to any regular shape; a flat upper surface to receive the bottom of the leveling rod being all that is needed.

The Earthen Sides to be Dressed off to the Level of the Spread Metal.—As soon as the metal is spread to the proper height, and before the consolidation of it is commenced, the earthen sides of the road are to be brought up to the proper level all along the edges of the metaling and given the prescribed slope to shed off the rain.

Rolling.—The metal being now evenly spread (with the proper sectional camber) over a convenient length of road, and the earthen sides raised along its edges, the whole surface is to be rolled with a 15-ton steam road-roller, and the rolling continued until the roller produces an even, uniform, hard surface over the whole road. Any depressions or unevenness occurring in the surface during the process of rolling to be promptly remedied by picking up with a pick the defective places and adding the requisite quantity of fresh stone to bring up the surface to the proper level.

The Metal Surface to be Watered while being Rolled.—After the road has been partially consolidated a water cart should precede the steam roller, as wetting the metaling causes the pieces to glide more readily together and to be more firmly bound together without crushing. The cost of the water cart will be more than compensated by the greater expedition with which the consolidation can be completed. This is my experience of the use of water. When a hard surface has been effected by the roller, broken stone screenings passed through a $\frac{5}{8}$-inch mesh screen, to be spread over the metaled surface to a depth of one inch, and the road again rolled, until its surface becomes such that water will run off it. The earthen sides being now finally dressed and rolled, the whole road is now completed.

Gravel.—Where broken stone is not procurable at a reasonable cost, or the exigencies of the local traffic does not oblige the use of so costly a material, while gravel is readily obtained, this material can be advantageously employed in making a good road. The difficulty in dealing with gravel is that it will not readily bind together under a roller, owing to the roundness of its particles, due to the attrition or manner in which nature has formed it.

Crushed Gravel.—If the gravel were crushed in a stone crusher, made to suit the smallness of its size, the difficulty due to its roundness would disappear; as the crushing machine would, by its action, produce enough of angularity or sharpness of sides in the particles to enable them to readily bind and not be easily displaced by the hoofs of horses. Thus crushed in a machine its consolidation would be effected in the same manner as described under the heading Broken Stone; with, however, this exception, that the consolidation of gravel must be effected in two layers of 3½ inches each, the first layer being in great part, though not thoroughly, consolidated before the second layer is added; the latter being then rolled until a hard compact surface results. A water cart should also precede the roller, as in the case of broken stone, after the surface has been partially rolled. For gravel a 10-ton steam road-roller will suffice, owing to the smallness of the particles. Gravel thus treated in a crusher would prove a fair substitute for broken stone where the traffic was not very heavy, and where it is readily procurable. It is far cheaper than stone, requiring in many cases to be but shoveled into a wagon, and it will cost less to crush and roll.

If, however, the gravel is to be used in its natural state,

as got from pits and the beds of rivers, a certain portion of dry, pulverized clay, in the proportion of one of clay to eight of gravel, must be mixed with it before it is spread on the prepared earthen surface or road-bed, on which it should be placed, as already directed, in two layers of three and a half (3½) inches each, and consolidated in the manner described in the preceding paragraph. A layer of about one-third of an inch (not more) of sand should be strewn over the consolidated surface, and the roller finally passed over it until the sand is absorbed in the gravel surface.

Coarse Sand.—I have also used coarse sand as a road material, the largest particles of which were about the size of peas. This will not make a first-class road in very wet weather, but will make a good dry-weather road, and will render an otherwise impassible road, in wet weather, such that a team will pull a load through somehow, as the expression goes. It is a cheap method of paving a fairly good road for nine-tenths of the year. It may be the forerunner of a good macadamized road, when the exigencies of traffic demand the latter. The sand should be screened so that a portion of the finer grains are eliminated from the mass. The road-bed should be prepared as previously described, and not more than two inches of sand spread at one time, and then rolled, the roller, a 10-ton steam roller, being preceded by a water cart. The road should then be open to traffic for a month or more, and then another layer of from one to two inches added, this again rolled, and so on, until some six or eight inches of coarse sand has been absorbed, when a fairly passable road in ordinary wet weather will result. Frequent rolling during the year will keep it a good road in fine weather and a passable one in

wet. Where, for miles, a road runs along a river or sandy creek, the procedure above described will prove a cheap method of paving a fairly passable road even in ordinary wet weather.

Trees.—Suitable shade trees should be planted along the lower berms reserved for such purpose. They should be planted six feet from the toe of the earthen embankment of the road, and 30 feet apart.

Mile Posts.—A first-class road may be said to be incomplete without mile posts. The initial point of measurement for these should be some prominent building in the city from which the country roads radiate. The mileage numbers should be of a size so that who rides may read.

THE REPAIR AND MAINTENANCE OF ROADS.

A road however well constructed will wear under traffic; and, therefore, repairs, and in time more or less renewal, of its macadamized or metaled surface is necessary.

The Effect of Traffic on a Metaled Road.—The first effect of traffic on a country road is the formation of ruts by the continuous passing of wheels over the same parts of the road. If these be not repaired or refilled they at length become so deep, and the crust of metal below proportionately so thin as to be unable to sustain the weight of a heavily laden wagon. The wheels then break through to the earthen base. The holes thus formed fill with water which softens the earth below, and every wagon wheel moving along the same line goes with a thud into these holes, increasing them in length, breadth and depth; and the road thereafter becomes an impediment rather than an aid to traffic. In a city there is not the same tendency to form ruts

as on a country road, as in the former the frequent changes of direction to avoid other vehicles produces a more uniform wear over the whole surface of the road.

How to Make Repairs.—As soon, therefore, as a rut or hole, or depression becomes one and a half (1½) inches deep on a broken stone road, or one inch deep on a graveled road, the rut or depression should be repaired or refilled in the following manner: The part affected should be cut out square (to use a well understood expression), as shown by the dotted lines, to the depth worn out, and the

space thus excavated refilled with the same description of fresh material to a height a little above the level of the sides of the excavation, so that it will sink down to that level when consolidated. If the rut or hole thus repaired be of small extent the section hand in charge of the repairs of that portion of the road should go over it with a stone or iron rammer, about 7 inches diameter, and weighing about fourteen (14) pounds, and ram it to a hard surface, using the material dug out of the hole, instead of screenings, for the top coat. If the rut repaired be of any appreciable length it should be gone over by a small road iron roller drawn by a single or double team according to the width of the rut, and the size or weight of the roller necessary to consolidate it. For the purpose of these repairs there should be a two-ton and four-ton roller on the road establishment, to draw which teams should either be kept or hired when necessary. The section man in charge

of repairs should always have the means at hand of repairing the road.

Repair Material.—To enable him to conveniently do so a certain quantity of broken stone should be stacked at every 100 feet along the lower earthen berm reserved for trees. The quantity thus stacked at intervals of 100 feet should not be less than a cubic yard of road metal, or 52 cubic yards to the mile.

Repair Implements.—The section hand should also be provided with a wheelbarrow, a pick, shovel, spade, four-pound hammer, and a road rammer, as implements for the execution of his work. When the repair material thus conveniently placed at his disposal has been reduced by use to about one-third of a cubic yard the stack should be renewed to the full cubic yard.

Repairs of Gravel Roads.—By the means just mentioned the section man will always have at hand the means of repairing the road the moment he considers such necessary. When a graveled road shows signs of roughness or disintegration of surface, the best remedy is to fill up all unevenness with the stated mixture of clay and gravel, and to pass a steam roller over it, preceded by a water cart or after a shower of rain.

Repair of Earthen Sides.—The earthen sides to be kept in repair by excavating the earth required from the side trenches. By this means the double object will be effected of keeping the trenches clean and free from drainage, and the earthen sides of the road in proper order.

Removal of Dust.—In France it has been found by experiment that a road wears better by removing the dust off it; this dust acting as emery powder does in the hands of

a jeweler. Where labor is cheap, the removal of dust might be effected by human labor, but I doubt whether it would be advantageous to do so in America. I have never seen a sweeping machine, such as is used on stone and asphalt pavement, tried on a macadamized or broken stone-road; but if it took off the dust without disintegrating the road surface, it might be advantageously used on that portion of a road within four or five miles of a city.

Renewal of Metaling.—When the general surface of any length of road is so worn as to be reduced to about $4\frac{1}{4}$ inches in thickness, a renewal of its surface is necessary by the addition of a coat of as much new metal as will bring it to the original thickness. The reduction of thickness from wear can be determined by exposing the stone bench marks placed, as has been directed, every 50 feet along the center and edges of the metaling. The old surface should be roughened up by means of a pick, and the new metal added and consolidated in the manner already described for the original metaling of a road.

County Engineer and Assistant Engineer. — For each county there should be an engineer and assistant, whose duties should not be solely confined to the earthwork and metaled surface of the road, but who should also have the designing and construction of all culverts and bridges required for the cross drainage that impinges along the road alignment. But these officials to be appointed by the County Commissioners from qualified engineers, of not less than eight years professional standing in the case of the engineer, and five years of his assistant. The salary of the former should not be under $1,800 a year, and of the latter not under $1,200, with ten cents per mile added in each

case for every mile traveled on duty; with the exception that no mileage allowance be granted for distances under five miles from headquarters or place of residence, permanent or temporary.

State Engineer.—There should also be a State or chief engineer, whose jurisdiction should extend over all the county engineers, who should submit to him all their plans for both road and bridge construction. The chief engineer should be competent to advise the county engineers on all matters pertaining to their duties. There would thus be a guarantee for efficiency and uniformity in all works undertaken throughout the State.

Minor Establishment.—For road repairs there should be a section hand in charge of the repairs of two to four miles of road according to the amount of traffic; and a foreman, with extra salary for a horse, for every 30 miles of road. When special repairs were needed, the petty establishment should, of course, be increased. There should be at least one steam road roller for every county, and a 2-ton and 4-ton horse iron roller for every 20 miles of road.

The present system of repairing and maintaining country roads, by exacting so many days' labor in the year from the farmers, should cease. It is obvious from what has been stated that roads cannot be maintained in good order under such a system.

Cost of Road Earthwork.—The cost of constructing roads in the manner directed in this treatise will vary, in the case of the earthen road-bed, according to the undulating or hilly nature of the country passed through. In the prairie lands of Illinois, Minnesota, Iowa, Texas, etc., the cost of the earthen road-bed will be from $500 to $800 per mile;

in more undulating land, from $700 to $1,500, and in hilly country from $1,500 to $2,500 per mile. Special miles will in each cost above these figures.

Cost of Broken Stone Metal.—The cost of the macadamized or metaled surface will vary according to the material and the distance it is transported. It will be from 50 to 75 cents per consolidated square yard, for a 6-inch consolidated thickness, if of broken stone ; or from $5,000 to $7,500 per mile.

Cost of a Graveled Road.—If the material be gravel, the cost will vary from 30 to 50 cents per consolidated square yard of 6-inch thickness, or $3,000 to $5,000 per mile.

APPENDIX.

The preceding notes and remarks on the construction of macadamized roads is the result of many years' experience in their construction in British India, in the Public Works Department of the Government of India. The country roads there are all macadamized or "metaled," to use a more familiar term in use there. They are also thoroughly maintained in good order; and taking the vastness of the country into consideration, and the efficient state in which the roads are kept, they may be said to form the most magnificent system of internal communication of that nature in the world. The Government of British India holds and acts up to the principle that it is as necessary to keep the country roads in good order as it is to maintain railroads. They each have their value, and in their way should be equally efficient. The first journey taken by all commodities is from the farm or field along a wagon road; and it is a just and right principle that the men (farmers) who convey these commodities to market and to the railroad depot should have every facility and convenience of doing so, which can be provided by good roads. The time and labor lost by the farmers in hauling their goods along bad roads adds to the price of their commodities—that is, to the food of the whole population, and to all the raw products of commerce; for the farmers must compensate themselves in some measure for the diminished power of their draught animals, and the extra wear and tear of their

harness and vehicles, caused by bad roads. In some transactions the loss suffered by one man is the gain of another, but in the case of bad roads there is a general yearly loss to the whole community of many millions of dollars. The Legislature of each State should therefore take up the matter, and establish such laws and regulations, and make monetary provision for the construction of so necessary a benefit to the general community as good roads. For further reference regarding roads, see *Harper's Weekly* of August 10, 1889.

An article by Jeremiah W. Jenkins, published by the American Economic Association.

An article in *Scribner's Magazine*, by N. S. Shaler.

Governor Hill's message to the New York Legislature on the necessity for constructing good roads.

The Engineering Record, of New York and London, for the latter half of the year 1889 and beginning of 1890.

THIRD ESSAY.

CONSTRUCTION OF ROADS.

BY JOHN P. PRITCHARD ("A SIMPLE SCRATCH"), QUINCY, MASS.

The first thing to do is to have the road properly laid out by a competent engineer, making lines and grades which include all earthworks, cutting and filling, culverts, drains, bridges, etc.

The earth road-bed to be free from loam; excavate to the required depth, then grade to the proper shape; to be well watered with a one-horse watering cart, and then rolled with the steam-roller; fill all depressions which shall appear with the same material as the road-bed, roll until it is compact and solid, then spread two inches of sand over all for a bed for the paving. On this road-bed set the paving stone, set a line of paving through the center of the road 9 inches in depth, then gradually diminishing to 5 inches to line of curb, the stone always to be laid with the best bed down, laid close and in parallel lines, as near together as possible, across the road, breaking joints. The stone for each section wants to be as near of a size as possible; no stone should exceed 15 inches, except through the middle of the road, then a single line can be laid

parallel with the road; after having paved 100 feet the stone must be wedged up tight with spalls, chips, etc. It is not necessary that the wedges should be driven to the bottom of the paving; after wedging, all the projections sticking up above the grade line of the paving should be broken off; no wedging to be done within 15 feet of the face of the paving; almost any kind of stone will do for the paved bottom if they are carefully and well set; after the bottom is thus prepared the steam-roller can be run over it, commencing at the curb; work towards the center; the amount of rolling for this bottom will have to depend on the superintendent of the work; never roll within 20 feet of the face of the paving; never use screenings from gravel to wedge or surface up the paved bottom.

On top of this foundation lay 4 inches of broken stone (when rolled), not to exceed 3 inches in size; the tailings and spalls from the breaker can be carted on to the road and men with hammers can break them to the required size, or, they can be thrown on top of the paving and used for wedging. Ballast and stone chips from stone sheds can be used for this course if care is taken to have them broken up to the proper size; in spreading this course never spread within 18 inches of the curb line; the roller will take care of this space by crowding it down to the curb line. There should not be any stone less than 2½ inches in this course; great care should be taken to pick out all the round stone that may appear, if not they will work up through the surface. This course is now ready for the roller, and a great deal depends on properly rolling this course. The flat stones must be broken or picked out as fast as they appear; the water cart can now be put on to the road; it will do

more good than to put on binding, which should be avoided if possible, and should never be resorted to unless the stone round up and will not bind; such places will occur when very hard and angular stone are used, but a few shovels full of binding and a little water will make them bind all right.

On top of this course lay 3 inches of broken stone that shall have passed through a 2-inch circular hole, and spread with a shovel; never use a rake; be careful and pick out all flat and round stones. Use the water cart freely on this course if dry weather.

On top of this course lay enough broken stone that shall have passed through a 1½-inch circular hole, and spread with a shovel thick enough to fill all interstices; to make it almost smooth this course wants more rolling than either of the others.

On top of this course comes the binding. Use the screenings from the breaker that have passed through a 1-inch circular hole, 2 inches thick. This course contains stone and dust, and when it is well watered and rolled, the dust and loam washed out of it, you will have a good surface, and it will be ready for public travel.

Sand can be used for binding instead of screenings, but in my experience screenings are more satisfactory for our roads.

The stone used in the second, third and fourth layers should be of one texture, as near as possible; the wear will be more even.

A great saving can be made in this class of road by paving a space through the middle wide enough for teams to pass both ways. The sides can be Macadam or gravel.

GRAVEL ROADS.

In building gravel roads commence and screen through a 2½-inch screen; then screen this through a 1½-inch screen; then this through a ½-inch screen; when the bed is properly shaped, wet and rolled, put on the 2½-inch, wet and roll; then put on the 1½-inch, wet and roll; then put on the ½-inch, wet and roll. The required thickness of each course will depend on the kind of road you are building. For main or side roads the custom in most towns is to take the gravel from the bank, dump it on the road, throw the loose stones into the bottom, and cover them up with the small ones; in a few years the small ones are on the bottom and the large ones are kicking about the top of the road.

MACADAM ROADS.

Have the bed properly shaped, wet and rolled; coarse stone ballast tailings from the breaker will do for the foundation course, but they must be well broken so they will be of even size. Next, a course of 2½-inch from the breaker, four inches thick; next course, 2-inch from the breaker, three inches thick; next course, surface up with 1½-inch, well rolled; cover with screenings from the breaker that have passed through the 1-inch circular hole. Great care should be taken to have the flat and round stones, as well as all rotten stone excluded; all courses to be well watered and rolled. Have the two last courses of one texture, as near as possible.

MAINTENANCE OF ROADS.

After a road has been properly constructed it should always be maintained, no matter what the amount of travel

there is on it. Ruts and hollows must be filled up as soon as they appear. No water should be allowed to stand on top of the road ; keep the road as free from dust and mud as possible. When filling ruts and holes, good hard metal that has passed through a circular hole, one and a half or two inches, should be used, loosening the bottom with a pick to facilitate the binding. To repair a Macadam road, put the spikes into the roller; go over it three or four times, pick out all the large stones or break them up, then run the roller over just enough to smooth it up a little, then put on the stone, never over 2½-inches in size, and for side streets 2 inches will do; then surface with 1½-inch size, wet and roll. You will not have to put any binding on this, for enough binding will work up through it if it is properly wet and rolled. The great trouble in regard to the maintenance of roads in Massachusetts is that in the fall, winter and spring, when the roads need looking after the most of any time in the year, the appropriations are all spent, the men discharged, and nothing can be done until after the annual elections; then they have no time to look after repairs, but get to work on new work, and before they get half done on the work laid out to do the money is all gone. We shall never have good roads in Massachusetts until the business of road-building is taken out of politics and taken charge of by the State.

Good roads can be constructed by towns, if they are not rich enough to buy a steam roller, but no town can afford to be without a stone-breaker ; and because a town does not own a steam roller or stone-breaker is no excuse that they cannot build good roads. With forty or fifty stone-breaking hammers, an iron sectional roller weighing

two tons, and a competent man as superintendent, good roads can be built. I built a mile and a half of Telford road before I even knew how to use a steam roller or a stone breaker. They will cost more though and take more time to build.

A good road plant consists of a 10 or 15 ton steam road roller, a 9x15 stone-breaker, and a revolving screen with 1-inch, 1½-inch, and 2-inch circular holes. A great saving can be made iu breaking stone by having the breaker set up 15 or 20 feet above grade, or an elevator can be used to convey the stone, and have the top of the mouth to the breaker even with the floor. This saves a great deal of handling the stone. One man can do as much as two where they have to be lifted from the platform. Another advantage of setting up the breaker is that hoppers can be constructed and the stone dropped direct into the mouth of the screen from the breaker, then three different sizes into the hoppers. Each hopper contains 40 tons. These hoppers can rest on a heavy frame of hard pine timber, high enough from the ground so that a cart can be backed under any of them, and by the simple motion of drawing a lever allows the contents of the hoppers to fall directly into the carts, and a reverse motion of the lever closes the slide tight. A cart can be filled in one minute. Three men can break 100 tons a day. Cities and towns will find it to their advantage to look into this mode of arranging their stone breakers. There is a stone breaker at work in a city near Boston that takes nine men and two horses to keep it going. The reason of this is because it is set on the ground, and the stones have to be handled over twice before they can be put on to the road. They are shoveled into the carts by hand

—but don't it make work for the poor laboring man? and don't we want his vote? That is the whole secret of bad roads in Massachusetts. Potter says bad roads have a tendency to make the country disagreeable as a dwelling place, and a town which is noted for its bad roads is shunned by people in search of rural homes. There is no kind of work done in the New England States that there is so much money wasted on as there is in building and taking care of roads. Shaler says, in no phase of public duties does the American citizen appear to such disadvantage as in road building. Learned says towns complain of the first cost of Macadam roads, while annually spending millions of dollars and moving countless tons of earth without having a good road. Whether I get the prize or not for this essay, if it can be called so, if my instructions are followed in regard to Telford road building by any competent superintendent, I shall have no fears as to the result, for I have been building just these kinds of roads since 1877, and some of them are having the heaviest traffic passing over them of any place in this country; talk about your thin roads—we would cut them up in one week with the rain-fall we have had this winter. I can't say anything about asphalt; I wish I could; I have never had anything to do with it, but I have great faith in it, and it will be the coming paving; it is only a question of time.

The roads that I have built are open for inspection. I have not given the cost of any of the roads that I have built, because the prices must vary according to the length of haul and price of stone. I built a mile of Telford road, 40-foot roadway, for $7,000. I have built a half a mile that cost $8,000. The first one, some of the material was

hauled over half a mile; the other, some of the material was hauled three miles. Seventy-five cents per square yard is the price quoted by the different road builders as a fair price for Telford roads.

Good sidewalks this season of the year are what we want. The best material for muddy walks is coal ashes; mix a little loam and loose fine salt; have it mixed up in large piles; when you have soft weather and the frost is coming out of the ground, you will find it a good deal better than gravel; it will bind and become compact, with a good smooth surface, and will shed the water. Every town should have a large shed where they could keep the good clean ashes that are collected and deposited ready for emergencies.

ABSTRACTS FROM ESSAYS RECEIVING HONORABLE MENTION.

In preparing the following abstracts of the essays given Honorable Mention, the purpose of the Committee of Award was to confine them to such propositions as were not substantially covered in the three essays published, and thus avoid unnecessary repetition. The omission of parts will, therefore, be understood as no reflection on the essays.

ABSTRACT FROM THE ESSAY OF PROF. JOHN V. HAZEN ("GRANITE STATE"), HANOVER, N. H.

Services of an Engineer Should be Secured.—The skill of a competent engineer is of great value in laying out roads. Figure 1 shows an old and a new road laid out in writer's native town. The new road is only 234 feet longer, and an elevation of sixty feet is saved and maximum grades are reduced from 1 in 4 to 1 in 10, and might have been reduced more.

Curving Roads not so Much Longer as They Seem.—Curving roads on a flat country are not so much longer as they seem. A road between two places, five miles apart, curving so that the eye can nowhere see further than a quarter of a mile, will only be 225 feet longer than a straight one joining the same termini. Within proper limits a road may wisely be increased in length by 15 times the vertical height avoided by the detour. See the map on page 87.

A Narrow Road Frequently the Best.—A well kept narrow road, when width is sufficient for traffic, is much better than a broad one with no greater amount expended for repairs.

Earthwork Paid for in Excavation.—Earthwork and rockwork should be paid for in excavation on account of shrinkage in the former, and increase in volume of the latter when placed in embarkment.

The Best Embankment Built in Layers.—Embankments are usually made by dumping the earth from their ends, keeping them up to their ultimate height, but wider at the top and narrower at base than when finished. The better system is to make them in layers of a foot thick, each successive layer being compacted by depositing those which follow.

Method of Underdraining.—For underdrainage in heavy soil, ditches are dug transversely of the streets, at intervals of 20 to 30 feet, and with a fall of from 1 in 100 to 1 in 20. The drain may be of stone or brick, built like a small culvert, or of agricultural tile. The latter are the most effective and generally cost no more. Two-inch tiles cost from $11 to $20 per 1,000 feet. They should be laid with above fall, with the closest possible joint, end to end, in a narrow

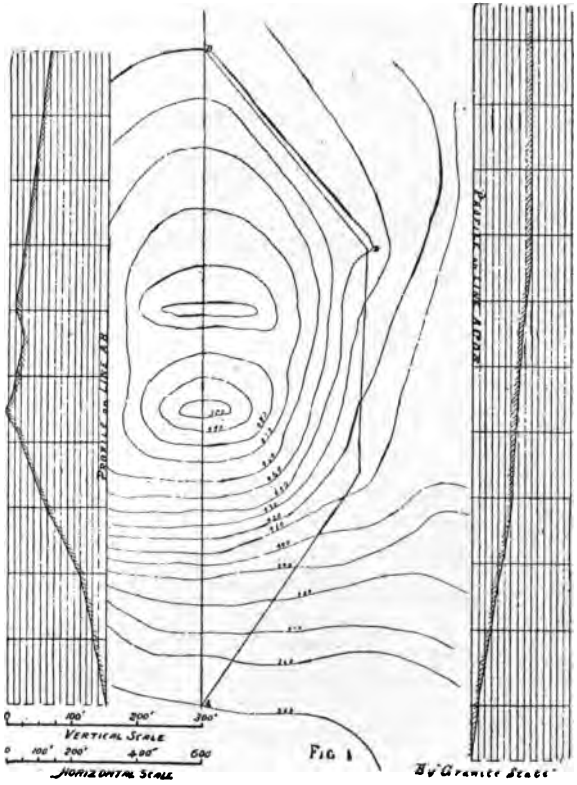

PROFILE ON LINE AB
PROFILE ON LINE AB'
100'
200'
300'
VERTICAL SCALE
0
100'
200'
400'
600
HORIZONTAL SCALE
B'
Granite Beds

FIG. 1

trench of uniform slope, carefully aligned. Such a drain placed 2 feet deep will cost, with tiles at $15 per 1,000, about 45 cents per rod when completed.

The English Method of Laying.—J. Bailey Denton, an English authority, advocates two lines of 2-inch tiles beneath the two edges of the traveled road longitudinally. Others place a line of tiles directly beneath the side ditches relieving them of much surplus water. This has the disadvantage of not much removing the moisture from center of the roadway. In another system one line of 3-inch tile is placed directly beneath the center of traveled road. This has the advantage of being cheaper than the others; of conveying away the moisture from center of the roadway, and, on the whole, is the most satisfactory. Cross drains connect at intervals the second and fourth systems with the side ditches, the latter being sufficiently deep to receive the outflow. Well built gutters, 18 to 24 inches deep below bed of road, with finished surface of side ditch above, kept clean, free from grass, weeds and stones, will frequently render underdrainage unnecessary, even in quite moist soil.

Culverts.—Culverts for transferring the water from the higher to the lower gutters should be put in at every depression. These may be of vitrified stone, 20 to 24 inches in diameter, oval or egg-shaped cement pipe of stone, brick, or of wood, if constantly under water. Culverts should have a fall of at least 1 in 100. Care should be taken to make them large enough to carry away the water without overflow. A rule sometimes used is $A = C\sqrt{M}$ where A = area of opening; M = drainage area in acres, and C = A coefficient depending on country; as 1 for a flat country, $1\frac{6}{10}$ for hilly, and 4 for mountainous.

Earth Roads.—While earth roads are not ideal roads, they are frequently the best a town's finances will allow. Their ordinary condition may be much improved by careful attention to grades, surface drainage, underdraining, and keeping the surface as nearly homogeneous and hard as possible. An occasional rolling will have a marked effect.

Amount of Rolling.—The total amount of rolling necessary will vary with materials and soil. From 30 to 60 hours per 1,000 yards is desirable. Silicious sand, clay, or clean sharp gravel is sometimes used as a binding material. The amount of crowning in use varies from $\frac{1}{48}$ to $\frac{1}{80}$ of the chord, or a slope of 1 in 24 to 1 in 40. Some engineers increase the slope with the grade. In Providence, grades of

0.5	to 4	feet per 100	have a	transverse	slope of	.04	per foot.
4	to 6	"	"	"	"	.05	"
6	to 9	"	"	"	"	.08	"

This provides for a rapid conveyance of surface water to side ditches. The total thickness of Macadam varies with the locality. Six to ten inches is the usual thickness. The latter being used in or near cities. Good roads have been made only 4 inches thick, and as it is often a question of thin roads, or no improved roads, they are worthy of trial. A 10-inch road costs from $1 to $1.75 per square yard, while good 4-inch roads have been built for 28 to 38 cents. Where the traffic increases, or sub-soil is soft, the thickness should be increased. Some engineers vary the thickness with the grades, decreasing it as the grades increase; 4 to 6-inch roads recently built near Plainfield, N. J., are said to have cost from $3,000 to $8,000 per mile; some 4-inch roads in Bridgeport, Conn., about $3,000 per mile.

Quality of Stones of Sub-pavement.—In Telford paving the spaces between the blocks should not be filled with anything smaller than stone chips, otherwise an essential characteristic, capacity to drain off rapidly whatever surface water works through, would be destroyed.

Total Thickness of Pavement.—The total thickness of Telford pavement will vary much with the locality and expected traffic. It should never be less than 6, and seldom more than 16 inches, and it may decrease as the grade increases. In cost they vary from 90 cents to $1.75 per square yard. Some roads recently built in New Jersey cost from $8,000 to $10,000 per mile.

Advantages of Telford Roads.—The advantages claimed for Telford roads are that the sub-pavement needs no renewal, and provides for thorough drainage. That in clayey, compressible soils the clay does not work up into the voids; that the broken stone does not work down into the soil; that extreme winter weather has no effect upon it, nor does the ensuing thawing out. The advocates of Macadam roads claim that the earth does work up into the voids of a Telford pavement; that the broken stone works down into the same voids, and that the broken stone wears out much more rapidly on a Telford sub-pavement than on compressed earth.

Good Foundation Important.—Foundations may be made of sand or blast furnace slag, compacted by rolling.

Repair of Earth Roads.—Earth roads should be kept smooth, hard, up to grade and cross-section by the addition of suitable materials at frequent intervals, and in small quantities at a time, on all places out of grade, securing a surface such as shall quickly convey the water to side

ditches. The latter should be kept open, of uniform and sufficient slope, free from rocks, ridges, depressions, and continuous to some natural or artificial outlet. Sprinkling and rolling are valuable adjuncts of repair, especially in dry weather, and a thorough rolling in spring, after ground has settled, is of marked benefit.

Sprinkling and Rolling Advantages.—In dry weather, sprinkling and running the road-roller backwards and forwards over a Macadam road will preserve its surface, or if water is not at hand a coating of sand or other binding material does the same.

Repair of Large Areas.—When large areas are repaired, the work, if possible, should be done in damp weather.

Thickness Worn out per Annum.—French experience shows that, measured by thickness, the annual wear on ordinary country roads is seldom over ½ inch, and on the most frequented roads 1 inch. Systematically maintained English roads confirm these results.

Cost of Breaking Stone and Repairing Roads.—It cost 70 to 80 cents per cubic yard to break trap rock with crushers; the cost of delivery varies with the distance, about $1.10 for two miles, or a total of $1.90. For ½-inch road, 20 feet wide, it will take about 164 yards, costing $300 per mile for material.

Plainfield, N. J., roads are said to have cost last year, with careful watching and immediate repair of weak spots, $1,000 for 40 miles. Time will show annual cost for complete maintenance.

Cost of Transportation on Poor Roads.—On a Macadam road, recently built in Connecticut, it is said that 5,000 pounds can be hauled where 1,200 to 2,000 was a good

load before rebuilding, for the same team. A farmer living ten miles from market, and having 100 tons annually to sell, on the unimproved road would have to make at least 100 trips, on improved road 40, a saving of 60 days' time, which, at $2.50 per day, would be $150; probably several times his tax for the improvement.

Low Rates Follow Good Roads.—The introduction of Macadam roads in parts of New Jersey is said to have doubled, in some cases, the value of real estate.

Kansas City has just renewed five miles at prices varying from $1.17 to $1.85 per yard.

The table on the following page shows the cost of some roads which have been recently built.

COST OF SOME ROADS RECENTLY BUILT, ETC.

Locality.	Total thickness of covering.	Method.	Cost per mile.	Remarks.
Kingston, R. I.....	8″	3 layers: 1st, 4″ of 1″ to 2½″ stone; 2d, 3″ of 1″ stone; 3d, screenings.	$5,500	1½ mile, 20 feet wide. ½ mile, 16 feet wide.
Linden Township, N. J.	12″	Telford, 8″; 2 layers broken stone; 1st, 2½″; 2d, 1½″ thick.	11,600	16 feet wide.
City of Rahway, N. J...	12″	" " "	9,349	" "
Union Township, N. J..	12″	" " "	11,900	" "
Westfield, N. J.....	12″	" " "	9,640	" "
Fanwood, N. J.....	12″	" " "	9,530	" "
Bridgeport, Conn.....	4″	Macadam.	3,000	18 feet to 20 feet.
Plainfield, N. J..... ...	4″ to 6″	" "	3,000	16 feet wide.
Fairfield, Conn.....	4″	" "	5,000	20 " "
Franklin Township, N. J.	4″	" "	4,700	15 " "
Hoboken to Paterson...	... ...	....	5,000	....

ABSTRACT FROM THE ESSAY OF SAMUEL L. COOPER ("PALISADES"), NEW YORK CITY.

Grades on First Class Roads.—It costs more to maintain a grade of 1 in 20, than a grade of 1 in 40.

Width of Roads.—The metal should be 16 feet wide for ordinary country roads, and as much wider up to 25 feet as the money available will permit; but for village roads and suburban pleasure drives, the metal should extend across the road to the gutter pavement on each side. Expense of making the metal 16 feet wide will sometimes compel a narrower width, but it should not be made less than 13 feet. as that is the minimum width on which wagons can pass each other with safety. The following are suggestions for dimensions of roads of different classes:

	Total Width.	Width Roadway.	Metaled Width.
For a First-Class Road	75 to 100	40 to 60	25 to 35
For a Second-Class Road	50 to 66	25 to 35	16 to 25
For a Third-Class Road	40	25	13

Crown.—When the surface of a road is poor the crown should be greater.

Consolidation vs. Mass.—Perfection in roads cannot be obtained without proper consolidation of the materials that make the road. This is more important than mere mass without consolidation.

Steam Roller.—It can best be obtained by a steam roller of about ten tons weight, and any community that seeks the best roads for the least outlay can get the most for its money by using the best materials, buying a steam roller, and employing an intelligent road builder to make the roads and maintain them.

For Macadam. — Each layer of stone must have a certain amount of binder to make it a compact mass. The best material for the purpose is screening from the crusher, but when that is not available, clean gravel and sharp sand should be used.

The rolling should be continued on the finish until water will flush over the entire surface.

Sides of Road to be Rolled.— The sides of the road between the gutters and the metal should be carefully graded and rolled to ultimate resistance and a true surface with a 5-ton roller.

The cost of Macadam roads in the vicinity of New York, by contract, to prepare the surface, provide good trap rock, spread and roll the same ready for use, is about :

50 cents per square yard for 6 inches of metal.
65 " " " " 8 " "
80 " " " " 10 " "

Foundation for Telford Road.—The foundation and broken stone will seldom be required to be thicker than 12

inches, and unless the width to be metaled is more than 16 feet, it should be of uniform thickness across the section. When the width is over 16 feet, the thickness at the sides may be reduced to 10 inches.

Foundation Stone, Size.—The foundation stones for a 12-inch pavement should be 7 inches deep, not over 4 inches wide on top, and from 8 to 12 inches long, and fairly uniform and regular. They should be of the hardest and toughest stone available, preferably trap rock, and laid with the joints widest on top, in parallel courses, breaking joints by at least 1 inch across the road. After being set, they should be wedged firmly by inserting and driving down with a bar, spalls of the same stone, in every possibly place, until the whole foundation is solid and firm. All irregulations and projections above the 7-inch line should then be broken off carefully with a hammer, so done as not to loosen the foundations. All the rest of the joints not then filled with spalls, should be filled with spalls and chips pounded in with a hammer, so that the top is a regular but not too smooth surface.

An 8-inch pavement should have a 5-inch foundation. The bottom course of stone should be broken to pass a 2-inch ring, and the top a 1-inch ring. The binding and rolling should be the same as above described. In the vicinity of New York the cost of a Telford Macadam road 12 inches thick is about $1.10 per square yard ; 10 inches thick is about $1 per square yard ; 8 inches thick is about 90 cents per square yard.

Six-inch Roads.—We are prepared to say that success is entirely possible with 6-inch Macadam roads, properly made and maintained.

Such roads can be built in the vicinity of New York for from $5,000 to $6,000 a mile, with a metaled roadway 16 feet wide, and when skillfully made, and thoroughly maintained, they answer all the purposes of a more expensive road; if neglected, however, they will soon go to pieces.

Essentials for Success.—The following are essential to success with 6-inch roads:

(1) Good stone, preferably trap rock, and screenings or gravel as a binder.

(2) A steam roller of about ten tons weight.

(3) The services of a man who knows how to make such a road.

(4) Constant and intelligent treatment in maintenance, particularly during critical periods.

Proper maintenance includes:

(1) The removal of the wear of the road, and its prompt replacement by new material.

(2) The immediate repair of ruts, holes and washouts.

(3) The keeping clear of the gutters and culverts.

(4) To these should be added additional care during critical periods, when the frost is leaving the ground, and during prolonged seasons of wetness or drought.

General Repairs.—In the fall of the year, the road should be put in first-class shape, to better resist the damaging effect of frost during the coming winter.

More general repairs, such as an entire resurfacing, will be necessary periodically, according to the thoroughness of the construction and the amount of traffic.

ABSTRACT FROM THE ESSAY OF FRANK B. SANBORN ("ROY"), BROOKLINE, MASS.

Records.—The expenses incured by the details of carefully located side-lines will not usually equal the cost of one of the many law-suits that the town will be obliged to withstand on account of indefiniteness of street lines.

Drains.—In an address before Maine Board of Agriculture, C. B. Stetson said: "It is clear that neither our farmers nor our road makers half appreciate the wonderful results which can be secured by thorough drainage of fields and highways—by keeping them, so far as water is concerned, in fit condition for perpetual service."

For the drainage of ordinary highways the writer recommends tile drains laid at least three feet deep in trenches 20 inches wide. After the tiles have been laid and the joints well protected with tarred paper or cheese-cloth the trench should be filled with small stones not more than three inches in diameter—the stones laying near the pipe should be carefully placed so as to protect it from the superimposed weight. Large stones which nearly fill the trench exert simply a downward thrust and should not be used. In ordinary soil a trench can be dug, the tiles laid and covered with stone, as described above, for 25 to 50

cents per linear foot. The writer has had charge of the construction of two roads the past year which were drained by 4, 6 and 8-inch tiles for 35 cents per linear foot. Henry F. French says in his book on Farm Drainage: ". . . drainage with tiles will generally cost less than one-half the expense of drainage with stone drains and be far more satisfactory in the end."

Road-bed.—It is preferable to make the width of driveway proper (which includes the gutters) some multiple of 8 feet, which is about the width necessary for each team.

Requisites.—It is better to bring good material, if necessary, from a distance, rather than make use of poor material for road-making.

Conclusion.—Finally, engineers of vast experience have concluded, that: A perfectly good road shall have a firm and unyielding foundation, good drainage, a hard and compact surface, free from all ruts, hollows or depressions; the surface neither too flat to allow water to stand, nor too convex to be inconvenient to the traffic; and free from loose stones.

ABSTRACT FROM THE ESSAY OF A. T. BYRNE, C. E. ("ZAMORA"), BROOKLYN, N. Y.

It is advisable for road constructors to abandon precedents and build roads which will best suit the requirements of the traffic.

The subject of the proper construction and maintenance of roads has never been considered by the people in more than a limited and superficial way. A lack of public appreciation of their true value, a mistaken idea of economy, and, in most States, the existence of laws that make and permit bad work, has made their condition a conspicuous blot upon the page of our general progress as a nation.

The system of requiring personal service upon our country roads by our rural population is unsound in principle, unjust in its operation, wasteful in its practice, and unsatisfactory in its results.

Road Laws.—New legislation is needed, but no legislation can produce good roads until the people are willing to pay for them.

New Laws.—First, the burden of the leading lines of communication should be borne by the whole community. Second, the employment of skilled engineers to superintend the road making and repairs. Third, the abolishment of

personal labor, and the levying instead of a money tax. The money tax will be found to be not only more equitable than the labor system, but even less burdensome. None of it will be wasted, and those who have the skill and strength for road-work will receive back in wages more than their share of it.

Roads and Morality.—Bad roads are the cause of more profanity and ill-nature than any other trial to which human nature is subjected.

Effect of Bad Roads.—Nothing has led farmers' children to a dislike of the country, and a desire for city life, more than the monotony of the rural districts in the winter months, produced by the lack of social intercourse, for the want of good roads.

Advantages of Good Roads.—By the improvement of our roads every branch of our agricultural, commercial and manufacturing industries would be materially benefited. Every article brought to market would be diminished in price; and the number of horses would be so much reduced that by these and other retrenchments many million of dollars would be annually saved to the public.

All the produce and industry which by these improvements finds for the first time a market, is, as it were, a new creation.

Cost of Roads.—The road which is truly cheapest is not the one which has cost the least money, but the one which makes the most profitable returns in proportion to the amount which has been expended upon it.

Maintenance of Natural Soil Roads.—In the maintenance of *sand* roads, the aim should be to have the roadway as narrow as possible, so as to have all the vehicles run in

the same track; to have an abundant growth of vegetation on each side of the rut, for by these means the sheering of the sands is in a great measure avoided. Ditching beyond a slight depth to carry away the water is not desirable, for it tends to hasten the drying of the sands, which is to be avoided.

Where possible, the roads should be overhung with trees, the leaves and twigs of which, catching in the roadways, will still further serve to diminish the effect of the wheels in moving the sands about. If clay can be obtained within a moderate distance, a coating six inches thick will be found a most effective and economical improvement; four inches of loose straw will, in a few days' travel, grind into the sand and become as hard as a dry clay road.

Clay roads can only be made into satisfactory ways by means of effective drainage, so contrived that the least possible amount of water will remain in the material. Deep side-ditches are absolutely necessary. Cross and sub-drains may be employed to great advantage. The narrower the roadway the more effective will be the drainage. If sand can be obtained within a moderate distance, a coating three inches thick will form a very beneficial improvement. Trees should be removed from the borders of the road, so as to expose its surface to the drying effects of the sun and wind. Neither sods nor turf should be used to fill holes or ruts, for though at first deceptively tough, they soon decay and form the softest mud; neither should the other extreme be reached, by filling up the ruts with stones. They will not wear uniformly with the rest of the road, but will produce hard ridges.

Coal-slack, ashes and cinders, judiciously applied, make fair roadways : yet in many parts of the coal regions the people are pulling through the mud in plain sight of heaps of that material sufficient to cover all the roads in their neighborhood, and are heard to lament the bad condition of the roads.

Stone.—The qualities required in a good road stone are hardness, or that disposition of a solid which renders it difficult to displace its parts among themselves, toughness, or that quality by which it will endure light but rapid blows without breaking.

Chemical Qualities.—The porosity or water-absorbing capacity is of considerable importance. Of two rocks which are to be exposed to frost, the one most absorbent of water will be the least durable.

For light traffic the carboniferous and transition limestones are sufficiently durable, make the smoothest and most pleasant roads, and possess the quality of forming a mortar-like detritus which binds the stones together, and enables it to wear better than a harder material that does not bind.

For heavy traffic the limestones are too weak, the sandstones too soft, the green stones too variable, the gneiss, quartz, and silicious rocks, though hard, are too brittle and deficient in toughness. The slates are inadmissible, the quartzose, feldspathic and micaceous granites are bad, the quartzose is too brittle, the feldspathic too easily decomposed, and the micaceous too easily laminated. The syenitic granites, which contain hornblendes in place of feldspar, are good, and better in proportion to their darkness of color; the traps and basalts are the best, though

most difficult to break up. The softer rock may be used for the lower course in a pavement.

Rolling.—The amount of rolling, with a heavy roller, should be about ten hours for each 1,000 square yards of surface for each layer of stone, but it must be continued until all motion of the stones has ceased. After several passages of the roller, any hollows which appear must be filled up with small material and the rolling continued. Each course is to be spread and treated in the same manner.

Watering is desirable where it can be done from the commencement of the rolling. It is done best by sprinkling. Excessive watering is to be avoided, especially in the earlier stages, as it tends to soften the foundation.

Binding.—Binding should be spread dry and uniformly in small quantities over the surface, and rolled into the interstices with the aid of watering and sweeping. By using binding materials in large quantities the amount of rolling is lessened, but at the expense of durability.

Wear and Maintenance.—When the wear on a road is confined to the crushing and grinding at the surface, it is the least possible, but when a road is weak from insufficient thickness or solidity on a yielding foundation, bending and cross-breaking of the covering take place under passing loads in addition to surface wear, and the effects are aggravated by the softening action of water finding its way into the road-bed through cracks formed in the surface, and by the disintegrating action of frost. Wear is measured by the loss of thickness in the covering. It is seldom found to exceed one inch per year on the most frequented roads.

Effect of Wheels.—Legislation is needed for regulating the width of wheel tires. With the same burden, a two-wheeled cart does far more damage than one of four wheels. Wheels with 2½-inch tires cause double the wear on a road than those do which have 4½-inch tires. No greater width is useful, as a wider tire does not bear evenly. The following proportions have been advised :

Load on each wheel.	Vehicle without Springs.	With Springs.
½ to ¾ of a ton...	6 inches.	1 inch.
¾ to 1 ton.....	4 "	3 "
1 to 1½ tons	6 "	4 "

Wheels of large diameter do less damage than small ones, and cause less draught for the horses.

AN ESSAY ON ROAD MAKING AND MAINTENANCE IN LESS THAN SIXTY WORDS, BY A. L. PHILLIPS ("TO THE POINT"), PENCOYD, PA.

First.—No unnecessary roads.

Second.—A competent engineer in charge of survey, location, construction and maintenance.

Third.—Proper Macadamized roadway from eight to four inches deep as needed, if cost of stone not prohibitory.

Fourth.—Use of roller in construction.

Fifth.—Complete drainage, sub and surface.

Sixth.—Constant, intelligent watching and repairing by permanent, responsible employes.

A PLEA FOR ÆSTHETIC CONSIDERATIONS IN ROAD BUILDING.

BOSTON, April 7, 1890.

To the Editor of THE ENGINEERING RECORD:

SIR: In your issue of March 29, you publish the first part of the First Prize Essay on Road Making, in which I was greatly struck by two rules that are laid down, which, from an artistic standpoint, would be more honored in the breach than in the observance. I call attention to them because they are an epitome of the standpoint of modern engineers with regard to æsthetic considerations. The two rules are: (in making a road) "make the line as nearly straight as practicable, and when changes of line occur connect them by regular curves of proper radius. When the line is intended to be straight make it so absolutely." These rules are, I am aware, considered obligatory by most engineers, for which reason an engineer may, in most cases, be depended upon pretty certainly to do a good deal toward spoiling the beauty of any landscape through which he may be called upon to make a road, with his "absolutely straight lines" and "regular curves of proper radius." It seems a pity that a few elementary ideas as to what constitutes beauty might not be instilled as part of the training

of a profession that has in its hands the making or marring of so much natural beauty. But probably to most engineers the idea of considering the possible effect of the line of a road on the beauty of the landscape, and planning the road with regard to this consideration among others, seems ridiculous and quixotic. I fear that the training of most engineers tends to blunt and deaden such ideas of beauty as they may have by nature, and leads them to regard beauty as a thing unworthy of serious consideration. And so it comes about that fine trees of a century's growth are ruthlessly cut down and hill-sides marred by deep and ugly cuttings, when a slight bend in the road would not only preserve the trees but add to the beauty of the road; or when by following the contour of the hill, with its natural and *irregular* curve, the road would be given some beauty and expense could often be saved. Among the rules laid down by the prize essayist I do not find any which speaks of the necessity of considering the natural conditions which *ought* to be among the determining elements of a line of road, when yet the capability to seize upon and make the most of these natural conditions ought to be one point of distinction between a good and an inferior engineer.

The æsthetic elements in the problem of making a road are not necessarily at variance with practical considerations. On the contrary, it will often be found that a consideration of these æsthetic elements will lead to practical benefits and economics. To consider these æsthetic questions, which are involved in a large proportion of engineering undertakings, would doubtless add to the engineer's difficulties. He would be less dependent on mere rule. It would give in each case opportunity for the exercise of

judgment and skill in the harmonizing of sometimes apparently contradictory requirements; but it would add greatly to the interest and individuality and value of his work.

I appeal to the engineers themselves to consider this question for a moment, not as engineers, but as individuals who may be affected by engineering operations, to free themselves for the moment from the strait-jacket of rules of their engineer's training and to consider how much beauty might be preserved, nay, might be added to our landscape, especially in suburban communities, by even the slightest consideration or forethought for beauty, for its own sake, and this often without any added expense or the sacrifice of any reasonable utilitarian requirement.

It is the wanton disregard of beauty without any corresponding gain against which I protest.

When our civilization reaches a point at which it is willing to sacrifice some utilitarian and material considerations for the sake of beauty it will mark a distinct advance. At present this is hardly to be expected.

H. LANGFORD WARREN.

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This book is a compilation of articles which have appeared in recent volumes of THE ENGINEERING RECORD, edited with a view of eliminating whatever was of timely or local interest, and arranged by divisions for convenience of use.

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